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Supply Chain Issues in Construction due to COVID-19: Challenges and Resilience Strategies from an Owner's Perspective

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The COVID-19 pandemic spread worldwide and affected all countries globally. The strict lockdown sent global economies plunging as it suspended all economic activities. The continuous virus spread had significant impacts on most sectors of the economy, including construction. The construction industry faced challenges, such as labor shortages, material shortages, cost escalations, schedule delays, delayed permits, delayed approvals and inspections, travel restrictions, and serious health and safety concerns among others which hindered the timely delivery of the construction projects. As a result, owners were under immense pressure, especially public universities as there were limited buildings to accommodate the increased teaching and research activities to meet current and future needs. The aim of this research was to investigate how higher education owners mitigated construction building material delays and shortages to deliver construction projects within the timeframe needed to facilitate teaching and research activities. The study was divided into three phases: In the first phase, an extensive literature review and preliminary interviews with the owners and contractors were conducted to explore the strategies adopted to tackle the supply chain issues and their effectiveness. In the next phase, data was collected through a questionnaire survey that included open-ended and closed-ended questions. In the final phase, data was analyzed, and guidelines of best practices were created for owners to tackle issues in future similar crises.

Key Words: COVID-19, Construction challenges, Owners, Supply-chain

Introduction

The recent global COVID-19 pandemic resulted in trade restrictions, bans, disruptions in the supply chain, and a deceleration in economic growth (Amphonsah and Frimpong, 2020; Bsisu, 2020; Raoufi and Fayek, 2022), greatly affecting the construction industry. In fact, the construction industry has remained largely unchanged for centuries, with only minor advancements, and often faces difficulties when confronted with unforeseen events such as pandemics, epidemics, or wars (Ayat et al., 2021).

The pandemic left a lasting mark on the construction of higher education facilities. Universities and colleges worldwide had to adapt rapidly to the challenges posed by the virus, resulting in significant changes to their construction and expansion plans. Major supply chain issues played the primary role in the construction slowdown and in some cases halted construction altogether (Helper & Soltas, 2021). This greatly affected higher education owners due to delayed construction, as well as the challenges of continuing to build with material shortages and increasingly prevalent and often complex delays (Assaad & El-adaway, 2021; Piro, 2020). Moreover, higher education owners have restrictions regarding how public funds are spent, which limits the early involvement of the designers and general contractors.

The purpose of the research described herein was to investigate how public higher education owners, were impacted by the COVID-19 pandemic and what actions were taken to ensure timely delivery of their capital projects to facilitate teaching and research activities in higher education environments. This research provides the owners with best practices, action plans, and a key to successfully navigating construction projects in times of crisis.

Literature Review

According to Helper & Soltas (2021), after manufacturing, the construction was the industry that was impacted the most due to supply-chain issues caused by the pandemic. Economic downturns and widespread market uncertainty prompted owners to reconsider investments in new projects and the continuation of existing construction projects during the first two years of the pandemic (Alsharif et al., 2021). However, many US cities and states deemed construction essential, thus construction was not necessarily shut down. However, due to supply chain challenges and labor shortages, some projects had to stop or look for alternative materials (French, 2022; Khalef et al., 2022).

The construction materials supply chain had a three-pronged issue - the lack of available materials, the logistics of getting materials to the jobsite from the manufacturers, and the understanding that some materials cannot be purchased early or until shop drawings were approved (Hildahl, 2022). These delays were found to be most problematic with raw or assembled materials obtained from overseas (Alsharif et al., 2021). The supply of construction materials was so significantly affected that companies dedicated a single person or team of individuals to be responsible for the procurement and delivery of materials (Z. Wang et al., 2020). Alternative materials or delivery methods were sought out particularly when customized products and fabricated elements were required (Alsharif et al., 2021). The contractor teams had to examine their schedules in greater detail to understand when a product was needed and actively contact vendors and suppliers to ensure timely delivery of the materials (Alsharif et al., 2021).

Late and delayed materials for construction projects became the new reality for construction contractors, which begs the question of what new methods of procurement may be adopted (Raoufi & Fayek, 2022). In 2021, experts predicted that “COVID-19 will have long-term ramifications for many aspects of the U.S. construction industry, including lead times extensions” (X. Wang, 2021).

Contractors were material sourcing from a variety of suppliers (local and national), buying early, and stockpiling in warehouses, ensuring timely delivery of the project and avoiding price hikes (Assaad & El-Adaway, 2021; Goodman, 2020). Contrary to lean practices and principles, just-in-time material and supply delivery did not work during the pandemic (Assaad & El-Adaway, 2021; Goodman, 2020). As a result, demand for warehouse and local storage space increased (Alsharif et al., 2021).

Most US companies were preferred higher inventory levels and favored supply chain resiliency over efficiency (Assaad & El-Adaway, 2021; Goodman, 2020). Although all the above-mentioned research is significant, specifically how higher education owners coped with supply chain disruptions during COVID-19 for the continued quality of education, improved industry practices and sustained financial efficiency has not been addressed in the current literature.

Methodology

Figure 1 shows the research methodology employed. After the initial problem identification, a questionnaire was developed consisting of open-ended and closed-ended questions. The dissemination of the questionnaire was done through email invitations. Purposive sampling combined with snowball sampling was adopted to obtain participants for the study. Purposive sampling is selected when researchers need participants to possess the information, knowledge, or experiences necessary for the study (Creswell & Clark, 2017). After gathering data from these initial participants, the researcher asked them to refer to individuals who might meet the criteria or have relevant experiences. This created a "snowball effect" that grew the sample size organically. This research required individuals who had served as higher education public owners or general contractors working on higher education projects before and/or during the pandemic.

The questionnaire was sent to owners overseeing projects valued at more than \$50 million and contractors with annual revenues exceeding \$100 million due to the substantial scale and complexity of the projects. This choice ensured a comprehensive examination of supply chain challenges and responses in contexts where the potential impact was most pronounced, providing valuable insights for addressing similar challenges across the construction industry. These projects were typically ground-up, new-construction buildings with complex materials and building components. The questionnaire was designed using Qualtrics and sent out to 170 potential respondents.

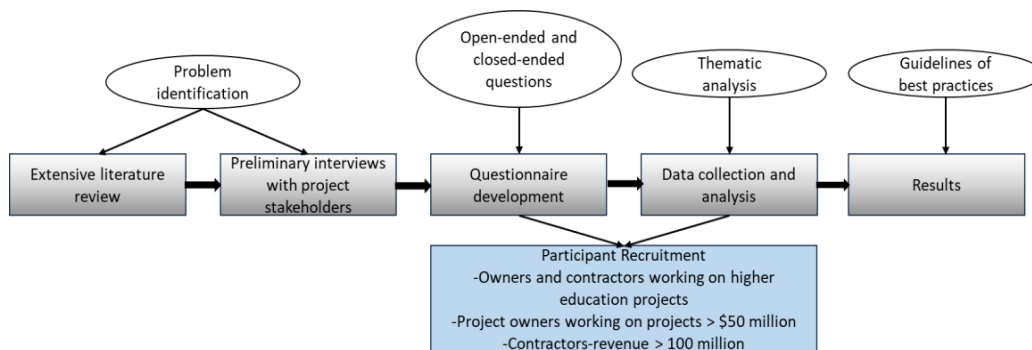


Figure 1: Research Design

The survey data was analyzed through thematic analysis, which is a method of analyzing themes and patterns in a data set (Tracy, 2019). For detailed data analysis, an iterative approach was used. Codes and themes were identified during the data analysis. Coding is the active process of identifying data as belonging to or representing some type of phenomenon” (Bhattacharya, 2017). The same code names were given to data explaining the same phenomenon.

Findings

Demographic Information of Respondents

The authors received 52 complete survey responses. The responses included 20 owners (38%), and 32 contractors (62%). Regarding professional roles, 27% of the respondents served as project managers, 50% held office and administrative positions, 8% were field supervisors, and 15% held other positions. Various contracting methods were used by the owners and general contractors as shown in Figure 2. Most higher education owners are not allowed to use Integrated Project Delivery or Best Value, which is indicated by the results. Contrasting, the majority of the higher education owners (17 out of 20) still use Design-Bid-Build as the preferred method of contracting. The larger contractors who were targeted for this survey preferred and used Construction Manager at Risk (28 out of 32), followed by Design-Build (22 out of 32), then Design-Bid-Build (19 out of 32).

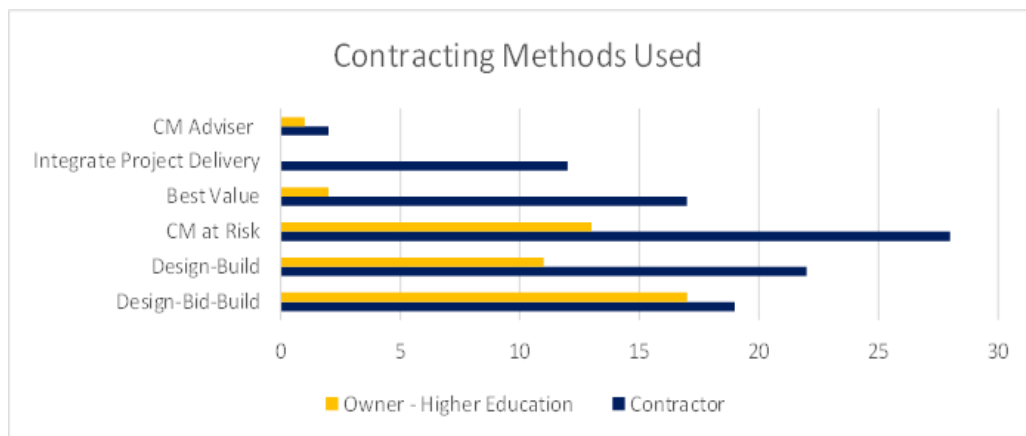


Figure 2: Contracting Methods Used by Participants

Survey Results

Distinct sets of questions were presented to owners and contractors. Owners were asked about supply chain challenges encountered during their capital projects and the methods employed to overcome these challenges. Conversely, contractors were questioned regarding their contributions to facilitating the timely completion of projects for the higher education owners.

Owners were asked as to what modifications they made during the planning and design stages of their projects concerning construction materials. As seen in Table-1, the number one item that owners could have done was to have early release packages to procure materials. Another top response was to bid early, then allow a long procurement time before requiring the contractor to start work onsite. By focusing on readily available materials, the owner could get their projects done timelier during construction.

Table 1: Owner Changes During Planning & Design Phase

Common Phrases / Themes	Top # of Occurrences
Early release packages	9
Bid early to allow longer procurement time prior to work onsite	6
Evaluate material availability / Sticking with standards that are available	6

General contractors were asked what the owner should have done during the construction phase of projects. As shown in Table-2, the top three items were monitoring material availability and lead times, limiting changes to only necessity, and making timely decisions and approvals. One survey respondent said, “When decisions are made and signed off, they need to move forward and not reverse course otherwise delays and impacts will happen”. Another question posed to the general contractors was what should the owner be doing during the planning and design phases of the owner’s projects. As seen in Table-2, the resounding top answer was for owners to have early release packages to procure materials.

Table 2: General Contractor Opinion on Owner’s Involvement in Project Phases

Common Phrases / Themes	Top # of Occurrences	
	Construction Phase	Design Phase
Monitor material availability and lead times through logs and schedules	10	
Limit changes to necessity only	8	
Timely approvals and decisions	7	4
Keep communication lines open with the team	6	
Buy materials early / Early release of long lead items	2	14
Complete construction documents / stop producing bad designs		6
Involve contractors and trade partners in design decisions		6

Results

Figure 3 illustrates the main solutions proposed through the questionnaire survey. The survey results were divided into two phases: the planning and design phase, and the construction phase. The owners mentioned the importance of tracking lead times throughout the project phases in an attempt to stay ahead. At times, they were compelled to prioritize projects and materials based on immediate needs, especially in preparation for the school year. An individual recounted a situation where they acquired roofing materials for one project while another person had to wait for theirs. In this case, the materials were borrowed to expedite completion of the higher-priority project.

The guidelines for best practices were proposed based on the data analysis. It was proposed that the owners need to work to create a more collaborative project environment by engaging not only the design team, but a contractor, who may act as a construction manager not at risk, local subcontractors, material suppliers, and anyone else who will be needed throughout the project. By establishing a team early on with everyone having a seat at the table so to speak, everyone can have buy-in on and take ownership of the project. Owners need to make sure that changes are limited to necessity only, such as material unavailability.

During the material selection process, when in a pandemic, the focus needs to be on what is available or can be locally sourced. When those items deviate from campus standards, then everyone on the team needs to be discussing lead times for that material or equipment. For those items, if the contractor cannot purchase the items prior to bid, then the owner needs to step in and purchase the equipment noting in the bid documents that it will be an Owner Furnished Contractor Installed (OFCI) item.

Guidelines of Best Practices

One contractor mentioned housing information in a Microsoft Power BI dashboard to communicate and track materials with major manufacturers on a monthly basis across the nation. Owners should be able to tap into the dashboard or create their own app/software to track materials. The dashboard could allow major manufacturers that would be used on these large capital projects to input the lead times that they are seeing for procurement of raw materials, production, and then assembly. This would help the owners to understand when bidding how they need to adjust their schedule and timelines to set realistic expectations with the end users.

Finances play an integral role in any construction project. Securing funding as soon as possible is crucial to get ahead of the lead times and procuring process. Many people mentioned that having a big enough contingency is necessary for material escalation, to pay for an expedited delivery, for storage or a warehouse, and to pay a higher premium to overcome labor shortages. The labor market goes where they get paid more.

The owners need to hold the design teams accountable for fully designed and completed documents. Without complete documents, the contractor and owner may have more changes later because crucial items were missed during design. This causes unnecessary delays. In addition, all key stakeholders need to be identified during the planning phase when at all possible. The owner needs to have the correct decision makers at the table, who are decisive and ready to make decisions.

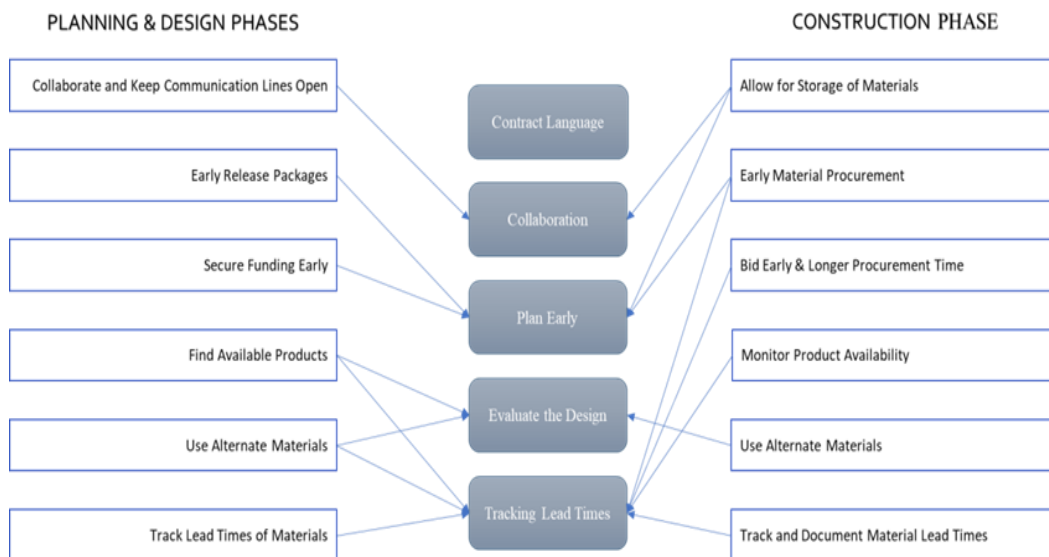


Figure 3: Research Findings Highlights

Conclusions

In conclusion, it is evident that owners must actively foster a collaborative project environment that involves not only the design team but also contractors, local subcontractors, material suppliers, and other essential stakeholders. By forming a comprehensive team early in the project's lifecycle, all parties can genuinely invest in and take ownership of the project. It is essential for owners to limit changes to necessary circumstances, such as material unavailability.

In the context of material selection, especially during a pandemic, the primary focus should be on what is readily available or locally sourced. When the chosen materials deviate from campus standards, lead times must be a subject of active discussion among the team members. In cases where the contractor cannot procure the items before the bidding phase, the owner should step in and purchase the equipment, explicitly noting it as an Owner Furnished Contractor Installed (OFCI) item in the bid documents.

Collaboration	Material Procurement	Financial	Other
<ul style="list-style-type: none"> Engage Contractors, Subcontractors, Material Suppliers as early as possible Owners, Design Teams, and Contractors communicate and work together to solve problems Limit changed to only necessity 	<ul style="list-style-type: none"> Be flexible with alternate material choices Track material lead times as early as Planning Phase Find a technology solution to assist in the tracking of material lead times Owner purchase during Design; Contractor install items 	<ul style="list-style-type: none"> Secure funding sooner to pay for early release of materials Build a bigger contingency for material escalation, expedited delivery fees, storage, and labor shortages 	<ul style="list-style-type: none"> Produce fully designed documents to minimize changes later Identify key stakeholders in the project who can make decisions quickly and not change their mind later.

Figure 4: Best Practices for Owners

Furthermore, Figure 4 presents the best practices for owners, including the implementation of information dashboards like Microsoft Power BI to facilitate communication and tracking of materials with major manufacturers. Owners should have the capability to access such dashboards or create their software to monitor materials, allowing them to adjust schedules and timelines realistically when bidding on projects.

Financial considerations are paramount in construction projects. Securing funding early in the process is crucial to outmaneuver lead times and procurement challenges. It is essential to maintain a contingency fund that is sufficiently robust to cover material escalation, expedited deliveries, storage solutions, warehouse facilities, and the higher premiums associated with labor shortages. In a competitive labor market, labor goes where it is compensated most lucratively.

Owners should hold design teams accountable for delivering fully designed and completed documents. Rushing through the design phase, only to later confront numerous changes during construction due to missed items, leads to unnecessary delays. Identifying all key stakeholders during the planning phase, whenever feasible, is of utmost importance. This ensures that the right decision-makers are present to address the client's needs promptly and decisively, minimizing project hiccups and enhancing overall efficiency.

Limitations

Although the research provides valuable insights, it is important to understand the limitations of the study. Firstly, the study's generalizability may be constrained by the specific context of the pandemic, which posed unprecedented challenges to the construction industry globally. The findings may not fully capture the diverse range of circumstances and responses in different geographical regions or under varying economic conditions. Additionally, the reliance on the questionnaire may introduce biases related to respondent interpretation. The study predominantly focuses on the perspective of higher education owners, potentially overlooking the experiences and strategies employed by other construction projects. Furthermore, the dynamic nature of the pandemic and its evolving impact on construction projects may imply that the identified best practices are subject to change as new challenges arise. Despite these limitations, the research offers valuable insights that can inform future studies and contribute to a more comprehensive understanding of construction project management during crises.

Future Research

Considering the immediate challenges posed by the COVID-19 pandemic, future studies should explore the long-term impact on the construction industry. Assessing how strategies implemented during the pandemic have shaped post-pandemic construction practices and resilience could provide valuable insights for sustainable industry development. A global comparative analysis of how different countries and regions coped with construction challenges during the pandemic could offer a broader perspective. Investigating variations in response strategies, regulatory frameworks, and their effectiveness would contribute to a comprehensive understanding of adaptable practices for diverse contexts.

Future research may also explore the role of technology in mitigating construction challenges during crises. Evaluating the adoption and effectiveness of digital tools, remote collaboration platforms that can streamline construction processes and can monitor material delays and shortages would be beneficial for future crisis management. Furthermore, building on the findings of this research, further exploration into supply chain resilience models specific to the construction industry could be undertaken. Identifying robust frameworks that enhance resilience against disruptions, considering factors such as global events, transportation constraints, and supplier dependencies, can provide a roadmap for future crisis preparedness.

By addressing these future research avenues, the construction industry can enhance its preparedness and responsiveness to unforeseen challenges, fostering a more resilient and adaptive environment for construction projects globally.

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