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Effect of Supply Chain Disruptions and Inflation on the Ohio Construction Industry in 2023

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Abstract. In 2023, the US (and the rest of the world) encountered supply chain disruptions due to the COVID 19 recovery, Russia's invasion of Ukraine, and the expiration of government subsidies during 2020 and 2021. The construction of many multibillion dollars facilities and infrastructure projects created additional demand. In 2020-21, COVID 19 disturbed the balance of the labor market; many businesses laid off a portion of their workforce; consequently, many workers retired, changed professions, moved, etc. creating a shortage of workforce. In addition, high inflation rates close to 10% in the US (and higher in many parts of the world) was the natural result of this supply chain disturbance and labor shortage. The authors hypothesize that these economic forces and challenges affected the construction industry which is a significant part of the US economy. This research attempts to examine this hypothesis through a survey designed to capture the opinions of construction professional. The research also tries to: • Determine the impact of supply chain disturbance, labor shortage, and inflation on the construction industry. • Figure out how the construction industry reacted to these challenges The findings of this research would give us a snapshot at the state of the construction industry, and it can help the industry deal with the similar challenges in the future.

Keywords. Inflation, supply chain, and construction industry

Introduction

Anecdotally, many construction professionals informed the authors (who live and work in Ohio, USA) that they were facing significant headwind dues to shortage of construction material and labor along with significant increases in labor wages during the second half of 2022 and 2023. Some of these professionals hypothesized that the construction of a giant Intel semiconductor plant (estimated at $28 billion) in the central part of the state of Ohio drove demand for construction workers and material. The plant construction increased demand for construction resources and services creating a temporary imbalance in the supply-demand equation. Naturally, in capitalistic economy, with higher demand than the supply capacity, the prices rise. In addition, the first author experienced (firsthand) difficulty finding contractors to reconstruct a portion of his house after a water damage event (in August 2023) due to labor shortage. These conversations incentivized the authors to investigate the impact of the supply chain disturbance, labor shortage, and inflation on the construction industry. Capturing a snapshot of the industry along with investigating how the industry reacted to this challenging environment may help the construction industry in dealing with such future challenges.

The rest of this paper is organized according to the following headings:

1. Literature review of

a. Macroeconomic drivers for inflation and supply chain disruptions in the US.
b. Inflation in construction material and services in the US, and
c. construction of high-technology facilities in Central Ohio.
2. Research questions
3. Research methodology
4. Survey results and finding
5. Research conclusion and recommendation
6. References

Literature Review

The authors examined published literature to identify the potential macroeconomic drivers for inflation and supply chain disruptions in the US and the world during the years 2021 and 2023. This investigation highlighted the economic events that shocked the US during the 21st century. The literature review also investigated the increased prices of the construction material and services in the US during these years. To paint a fair and complete story, the reader must know about the construction of high-technology corridor and facilities in Central Ohio that significantly increased the demand for construction material and services.

Macro drivers for inflation and supply chain disruptions in the US

After the collapse of the Soviet Union in 1990, the world economy slowly changed from a bipolar trade to global trade system/world order. Governments and businesses engineered supply chains for the needed goods and services that utilized intellectual resources in the developed countries, capital movement, cheap labor in developing countries, and global raw material. The admission of China into the World Trade Organization in December 2001 accelerated the perfection of the manufacturing supply chain creating an environment of low inflation for 20 years. The lower cost of shipping goods from a manufacturing facility to the next facility assisted in creating very specialized manufacturing facilities all over the world with China gaining the lion share of this global manufacturing. Over time, the global supply chain has been gradually finetuned and almost reached perfection. Producers outsourced manufacturing functions and invested in facilities in areas with low-cost labor; they also outsourced some design, management, and customer services to lower-cost regions in the globe reducing production cost further. The digital technological revolution that enabled cheap audio, video, and data transfer accelerated the outsourcing process. In addition, competition among producers and sellers kept prices at bay; consequently, inflation was contained in the range of 2-3% during most of the 21st century. The perfection of the supply chain enabled China to maintain economic growth rates exceeding 7% per year and partially kept inflation at bay in the US and European Union during this period. China, consequently, lifted more than 300 million capita from poverty to middle class and created a class of millionaires and billionaires (The World Bank Group, 2023).

A supply chain disruption is an event that causes disruption in the production, transportation, or distribution of products due to natural disasters, regional conflicts, and pandemics (Arena, a PTC Business, 2023). The above-mentioned supply-chain perfection made the world economy more vulnerable to supply chain shocks. The COVID 19 epidemic forced many countries (all over the world) to shut down their economy during the first half of 2020 due to lack of knowledge about virus and high death rate. During the rest of 2020 and a good part of 2021, manufacturing all over the world kept on sputtering as many employees worked from home and only essential workers were working in the factories. China kept combating the virus by using the zero Covid policy that led to complete shutdown of large provinces, counties, and townships in 2020 and 2021. In addition, China prioritized Chinese industrial needs over international needs; this was evident in the medical supplies. The

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n created many supply chain bottle necks that the manufacturing sector had to deal with. In addition to the supply chain disruption by COVID 19, Russia's invasion of Ukraine and the sanctions imposed on Russia along with the blockage of the Black Sea worsened the supply chain disruption and increased inflation throughout the entire world.

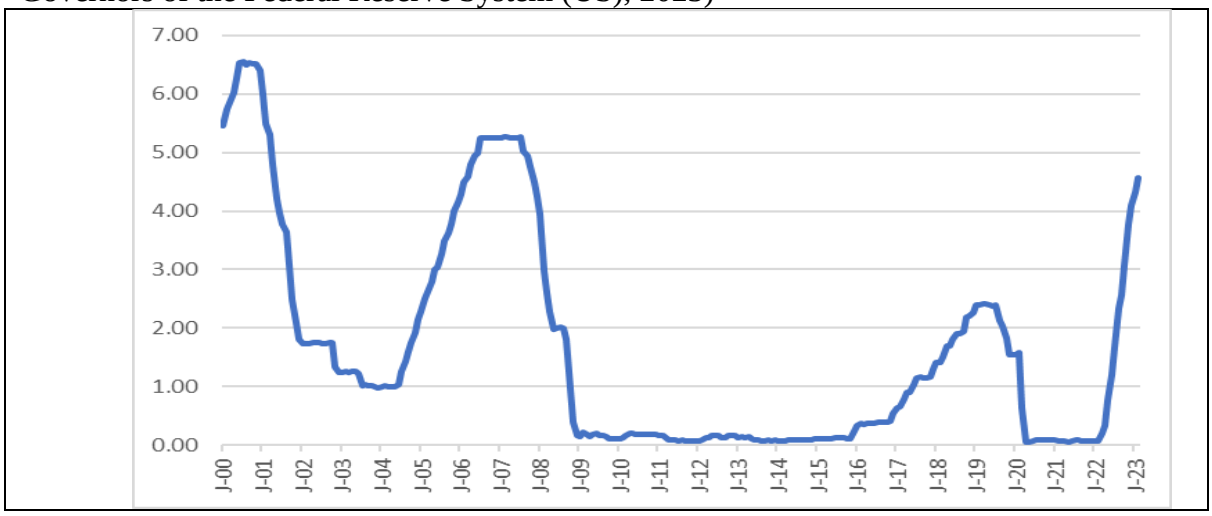
The American and European businesses and governments started to diversify their supply chain to within their borders and to countries other than China disturbing the established world order. The reasons for these changes included:

- At the peak of the Covid epidemic, China prioritized the satisfaction of the Chinese industrial needs over fulfilling the international needs.
- The embargo on Russia due to its invasion of Ukraine forced many western firms to exit Russia.
- Western business leaders realized that they cannot exclude the possibility that China would invade Taiwan forcing them to exit China.

Macro drivers for inflation in the US

The inflation driving forces-related to this research-had global, national, and local dimensions; yet the global and national ones are overlapping. The US went through several events that changed the economic landscape and introduced significant economic challenges that drove the economic policy makers to take certain actions during the 21st century. Chief among these policies is the adjustment in the central bank interest rates. The 9/11 attack (on the World Trade Center in New York and the pentagon in Washington, DC) along with the bursting of the internet bubble of the late 1990s significantly slowed down the US economy. Consequently, the Federal Reserve Board (FRB) significantly lowered its interest rate (which governs the banking lending rates) from close 6.5% to 1% as shown in Figure 1.

Figure 1. The Monthly Federal Reserve Rates from 2000 to 2023 (Board of Governors of the Federal Reserve System (US), 2023)



Due to the technology financial bubble burst in 2000 and the 9/11 attack on the World Trade Center in 2001, the FRB kept interest low (around 1-2% from 2001 to 2005 to incentives businesses to borrow funds to start new businesses ventures and expand existing ones. This lengthy low-interest-rate environment encouraged financial investments banks to create financially engineering mortgage instruments. In 2005, the FRB raised interest rate from 1% to 5.25% around the end of 2006. Consequently, with the rise in interest rates, these financially engineering mortgage instruments caused the mortgage crises of 2007-2008 that paralyzed many global banks and forced many well-established investment banks into bankruptcy. This fiscal crisis significantly slowed down the world economy and kept inflation at historic low levels from 2008 to 2021 as presented in Figures 2 and 6.

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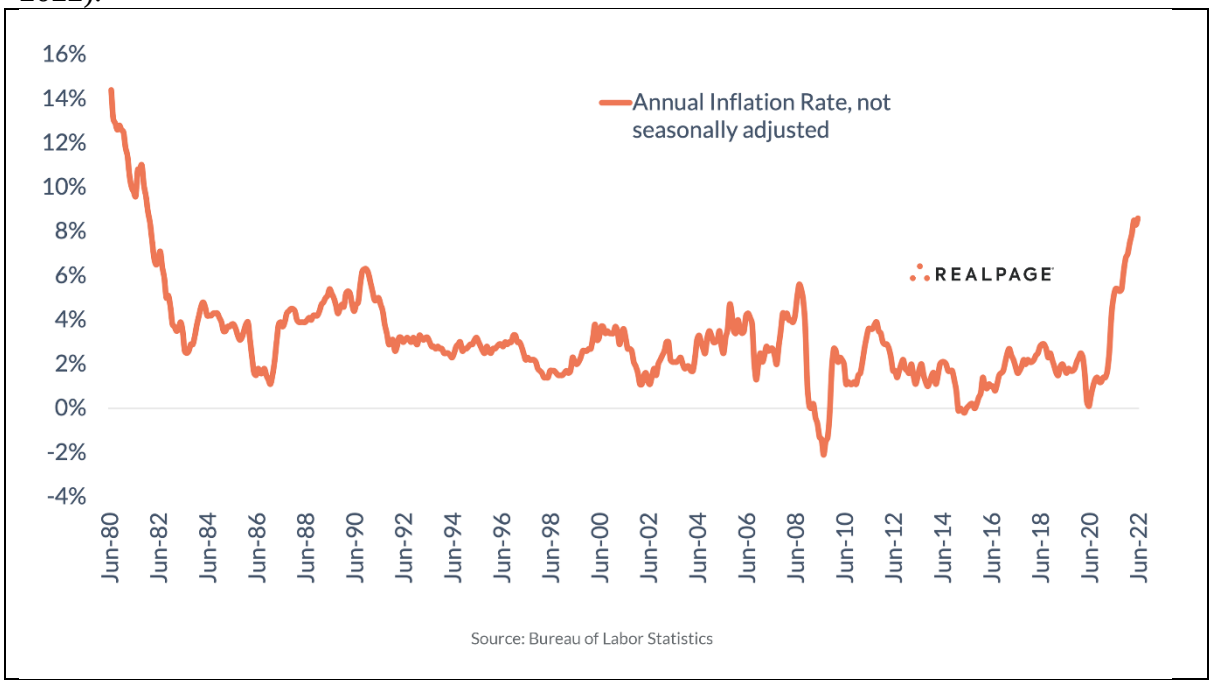
Figure 2. Annual inflation rates (without seasonal adjustment) from 1980 to 2022 (Wheeler, 2022).



Consequently in 2008, the FRB and major global central banks lowered their basic interest rates to slightly above zero to avert severe recession. In addition, the Federal Reserve pumped trillions of dollars into their economy through their quantitative easing policies. In 2017, the FRB started to increase the interest rate encouraged by strong economic growth and low unemployment. When the world economy shut down due to COVID 19, the central banks kept interest rates very low during 2020 through 2022 creating fertile environment for inflation. In defense of the Federal Reserve, the US inflation and economic growth rate during most of these 22 years was around 2-3% as shown in Figure 3. The combination of historic low interest rates, slow- but sustainable economic growth, and low inflation created a goldy lock environment which created sustainable economic growth and low inflation in most of the world.

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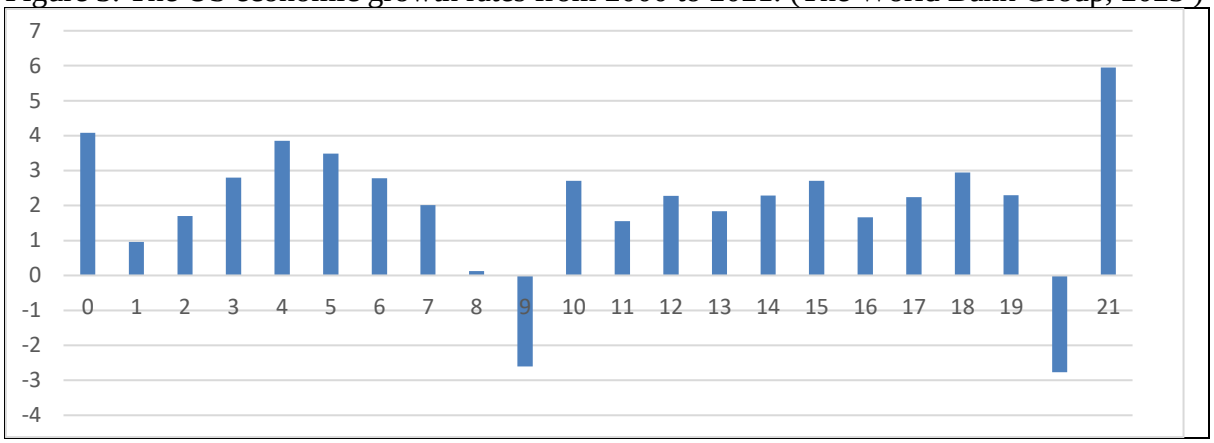
Figure 3. The US economic growth rates from 2000 to 2021. (The World Bank Group, 2023)



Around the end of the first quarter of 2022, the US and the industrialized world, started to gain confidence about dealing with COVID 19. More than half the population have been vaccinated and a good part of the other half have developed some immunity because they have been infected with the virus. The whole US and the industrialized nations simultaneously tried to operate at full capacity as much as they can. However, the supply chain shocks due to COVID 19 and Russia's invasion of Ukraine hampered the world's ability to operate at full capacity. The authors hypothesize another two more driving forces for inflation:

(1) The rich countries pumped trillions of borrowed-governmental dollars into their economy to prevent great depression. These funds created excessive capacity to purchase goods and services once the fear of COVID 19 subsided.

(2) Misjudgment of the central banks, world wise, about the sticky nature of inflation in late 2021 and early 2022 as they diagnosed this inflation as transitory. The delayed response of the central banks, due to the fear of recession, exacerbated the inflation to a level that has never been seen since the late seventies.

Despite the efforts of global governments to reduce laying off workers, businesses laid off a good percentage of their workers to offset reduced sales. Many of the laid off workers changed their profession/trade and/or relocated to lower cost areas. In addition, the workers, who were close to retirement, retired. Consequently, when the businesses attempted to reach full production capacity, they did not find the needed workforce in terms of quantity and quality. Consequently, businesses were forced to offer higher wages and salaries to attract workers, increasing the production cost as shown in Figures 4A and 4B.

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Figure 4A. Difference between the inflation rate and growth of wages in the United States from January 2020 to April 2023 (Statista, 2023)

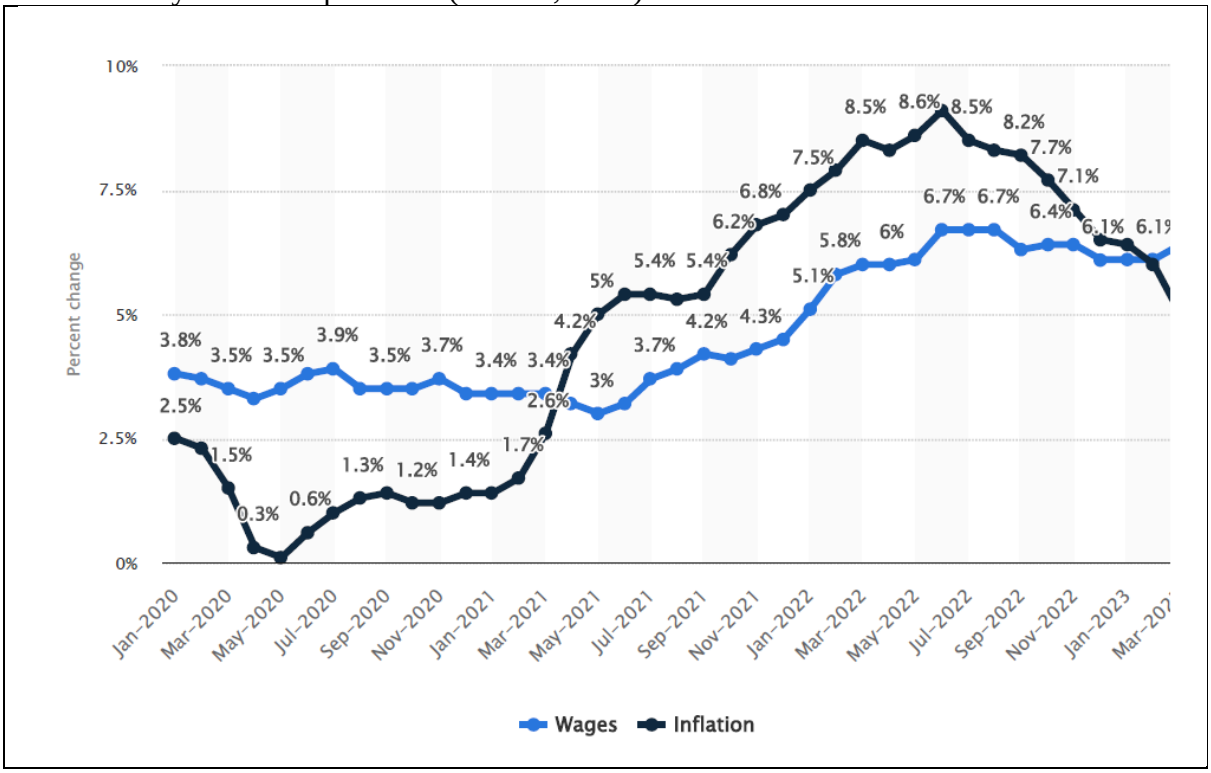
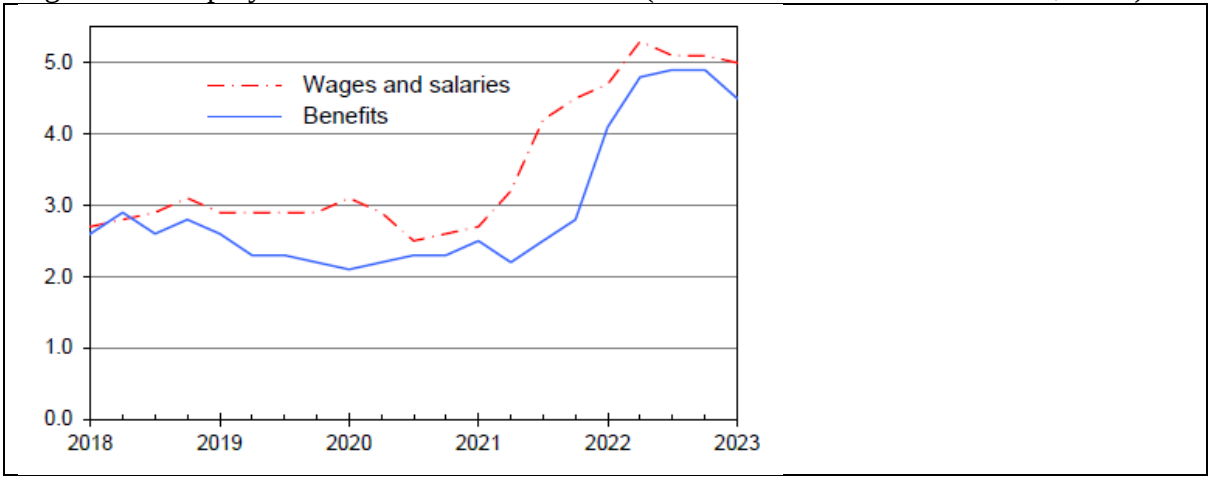


Figure 4B. Employment Cost Index 2018 –2023 (U.S. Bureau of Labor Statistics, 2023)



Silicon Valley in the Heartland

As the above-mentioned inflation and supply chain disruption were accelerating around the end of 2022 and the beginning of 2023, Intel broke ground on its state-of-the-art semiconductor manufacturing plant in New Albany, just outside of Columbus, OH on Sept. 9, 2022 (City of New Albany, 2024). Intel is investing more than $28 billion in the construction of two new leading-edge chip factories to boost production to meet demand for advanced semiconductors and power a new generation of innovative products. The site has the capacity for a total of eight fabs, but more importantly it will create a high technology ecosystem that supports the operations of many partners (Intel Corporation, 2024). This is the largest single private-sector company investment in Ohio's history (City of New Albany, 2024). This project absorbed the local construction resources (material, skilled and unskilled labors, equipment, and subcontractors) drove further the local inflation and supply chain disturbance.

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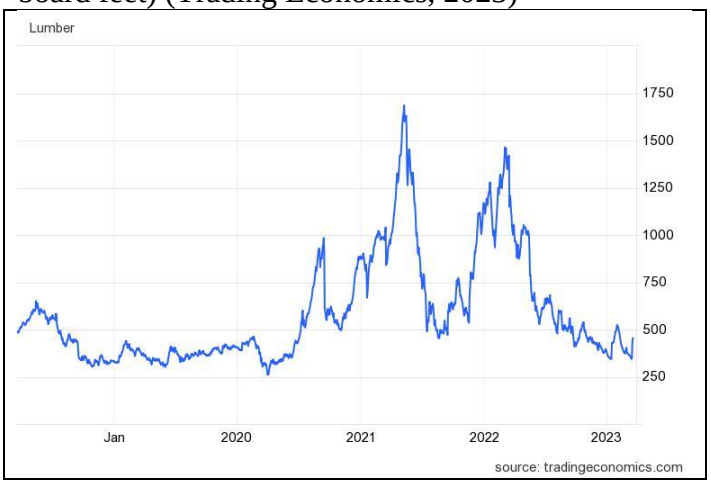
Valley companies are expanding in Columbus, Ohio, which is dubbed the 'Silicon Valley' of the Midwest causing a boom in real estate development in Columbus (Bro, 2024). The Intel project is built in two phases; the construction contract for the first phase, scheduled for completion in 2025, was awarded to Bechtel Corporation. This facility creates a mini–Silicon Valley eco system around it and increases the need for services and products in the area. (Blackridge Research & Consulting, 2024). For example, Montauk Innovations LLC, a subsidiary of Google, acquired a 447-acre parcel in the New Albany International Business Park. Google announced the building of a $600 million data center that could cover about 275,000 square feet when it is finished (Baxtel, 2024).

Article I. The Construction Industry in the US

The construction industry is commonly regarded as a bellwether industry because it has a major influence on the economic health of the country. When the construction industry is prospering, new direct and indirect (materials and equipment manufacturing) jobs are created. It creates about 12% of the total gainful employment in the United States with an annual sales volume of @ $1.75 trillion. Approximately 80 percent of construction is privately financed, and 20 percent is paid for by various public agencies. The construction industry can be broken down to four divisions: residential, commercial, heavy/civil/highway, and industrial. Each division employs a different set of construction equipment requirements, methods, trade and supervisory skills, contract types, and financial arrangements. Residential construction typically accounts for about 40 to 50% of new construction in the US. However, residential construction has been characterized by instability of market demand and is strongly influenced by governmental regulation and national monetary policy. A considerable proportion of housing construction is financed through private financial lending institutions with mortgage guarantees from the public sector (Clough, Sears, Sears, Segner, & Rounds, 2015).

Trading Economics (2023) illustrated the changes in the lumber prices over the last 5 years (USD/1000 board feet) in Figure 5. The figure shows that lumber prices increased significantly during the second half of 2020, then they went down twoards the end of 2020 and beginning to 2021 to go up and down again later in 2021. Similar cycle again repeated itself in 2022. In part, these ups and downs in lumber and many other material gave credit to the conclusion that inflation is transatory not sticky during the second half of 2021. This ups and downs in essential construction material like lumber provided a challenge to construction project managers.

Figure 5. Lumber prices 2018-23 (USD/1000 board feet) (Trading Economics, 2023)



Construction Material Prices over the Last Five Years

Because the construction industry is one of the largest single industries in most economies, it is natural to theorize that the above-cited inflation and supply chain disruptions affected the construction industry. Figure 6 illustrates the consumer price index along with the construction material price index using the year 1990 as 100. The graph (whose raw data was obtained from the Federal Reserve Economic Data) illustrates that inflation of the construction material (during the period from 2021 to 2023) was higher than consumer price index, which was the highest for the last 50 years.

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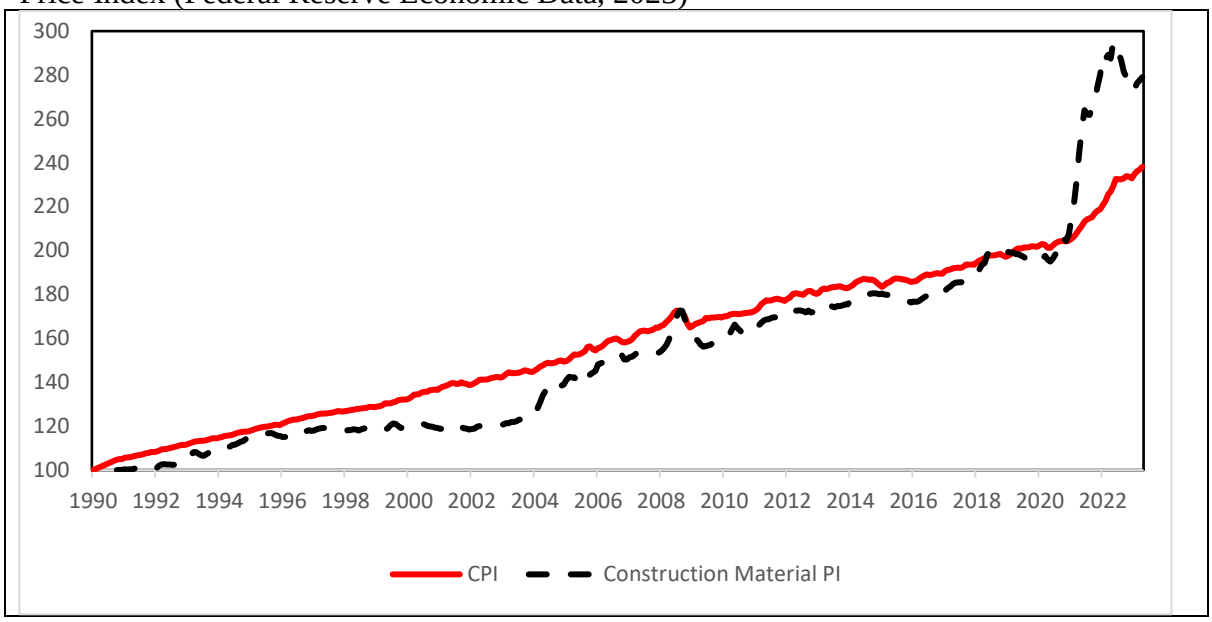
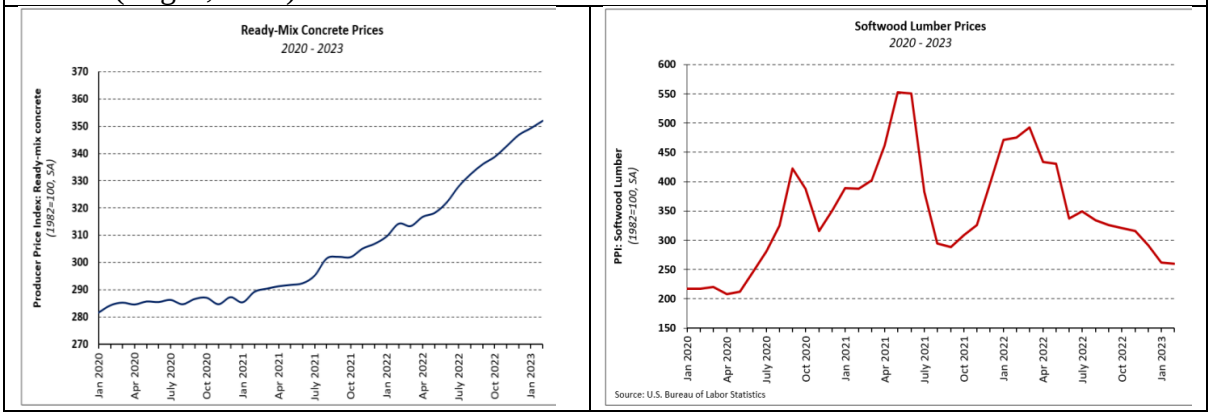
6. Consumer Price Index (Federal Reserve Economic Data, 2023) & Construction Price Index (Federal Reserve Economic Data, 2023)



Lumber, concrete, and rebar are major construction material world wide. Figure 7 presents the softwood lumber prices and ready-mix concrete prices during the period of 2020 to 2023 in the US (Logan, 2023). The figure shows that the lumber prices increased significantly during the second half of 2020, then they went down twoards the end of 2020 and beginning to 2021. The prices climbed up and down again later in 2021 and they had a similar cycle again in 2022. On the other hand, the ready-mix concrete prices were in steady increase during the same period.

Figure 7. Ready-mix concrete prices (left) and softwood lumber prices (right) 2020-2023 in the US (Logan, 2023)



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Gilbane Building Company (in its Construction Market Conditions Report-Q2 2022) reported the amount of delay of several construction material as shown in Table 1. The electrical and HVAC material and equipment experienced the highest level of delays because much of these materials and equipment are unique to the specific projects and are manufactured to order due to their cost and manufacturing complexity (Gilbane Building Company, 2022).

Table 1. Building material and the amount Of delay (Gilbane Building Company, 2022)

Material	Lead Time
Generators	72-95 weeks
Switchboards	45-80+ weeks
Chillers	42-52+ weeks
AHUs	40-75 weeks
Panelboards	30-52+ weeks
Switchgear	30-80+ weeks
International Fabricated Millwork	24-28 weeks
Elevators	20-48 weeks
RTUs	20-30 weeks
Curtainwall	14-28 weeks
Steel	12-30 weeks
Roofing (Select Materials)	4-20 weeks

The supply chain disturbance unbalanced the supply and demand forces leading to an increase in the prices of building material and equipment. Figures 8 and 9 present the changes in prices of the essential construction material during the period from Q4 2020 to Q4 2022 based on the Cost Index - Chicago Q4 2022 (McGreal & Van Anne, 2023).

Figure 8. Material Pricing Change 2009 -2022 (McGreal & Van Anne, 2023)

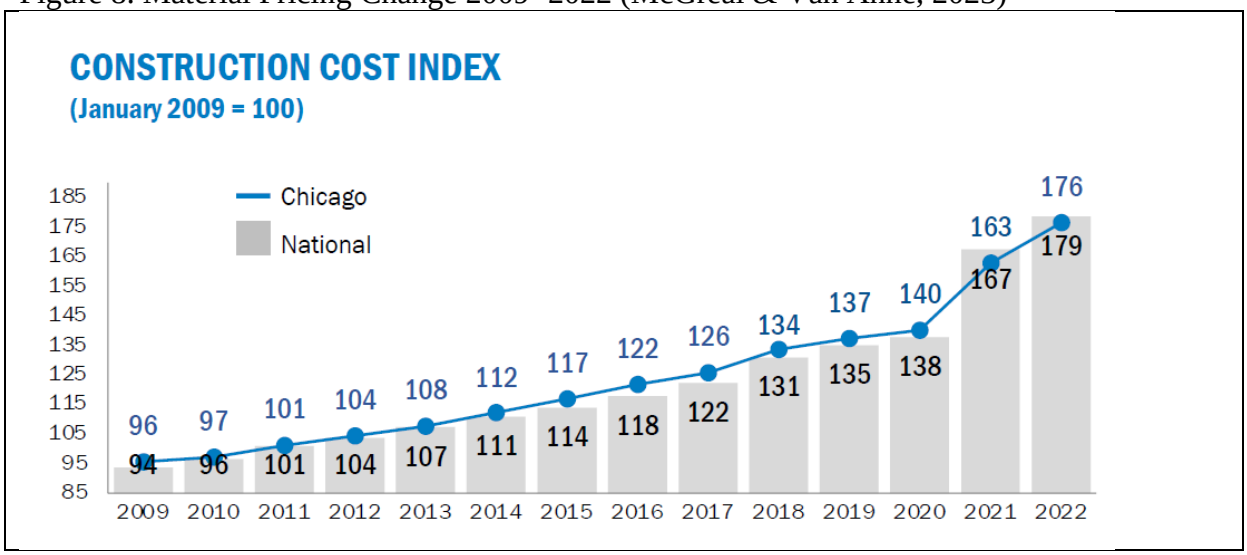

Figure **9**. Material Pricing change Q4-20 to Q4 22 (McGreal & Van Anne, 2023)

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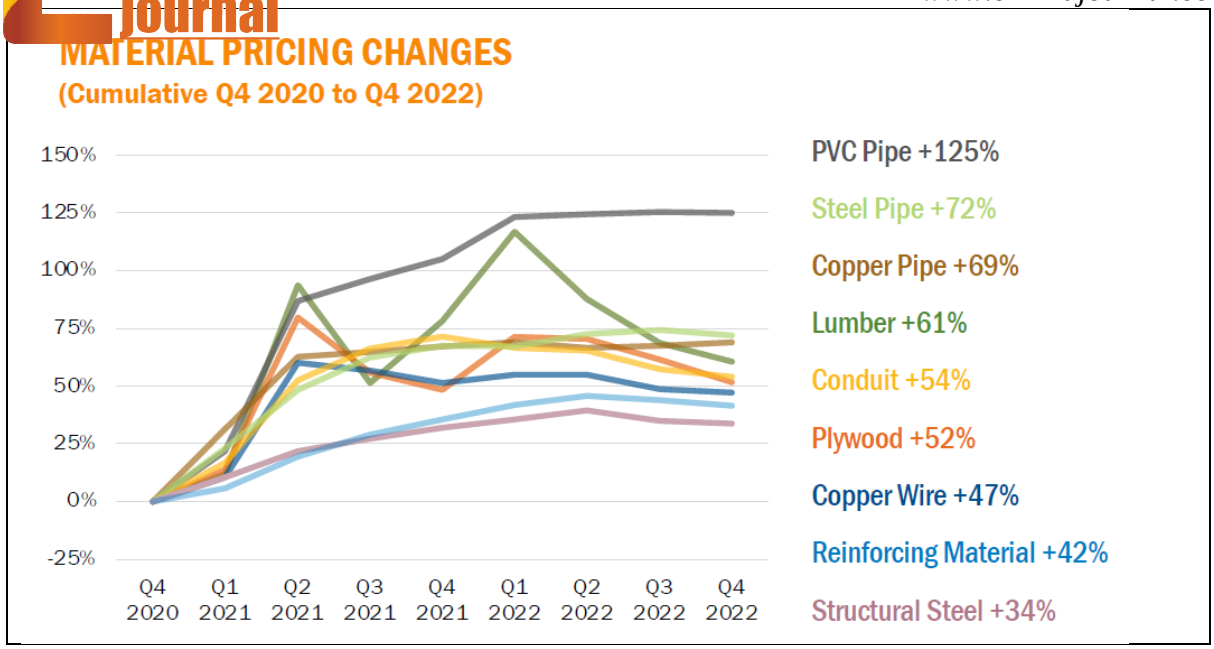

Research Questions and Methodology

Anecdotal conversations with many construction professionals about supply chain disturbance (combined with high inflation) motivated the authors to research their impact on the construction industry in Ohio as a proxy for the US and how the industry reacted to these drivers/forces. The literature review confirmed these forces along with their macroeconomic magnitude, but their impact on the different parties of construction projects was not fully explored. Which of the different sectors of construction industry experienced these disturbances and how much the material/systems components of the construction projects have been impacted? Did the size of the construction firms have influence on its ability to absorb the impact? How construction firms and project owners reacted to these forces and operated in this environment.

Research Methodology

In addition to reviewing literature about inflation and supply chain disruptions, asking the construction professional who dealt with these disturbances to inform us about their impact gave us another insight. The authors used this insight to develop a survey to collect the answers to the research questions. The survey, which is included in Appendix I, is composed of the following sections:

- Demographic questions to see if the impact differs among the subjects based on the different types of construction work, the subject's role (general contractor, subcontractor, Engineer/architect, etc.) on the project, and the sales volume of the subject's firm.
- The magnitude of the impact on the different construction material and equipment.
- The extent of wage increases to the firms' labor workforce along with the type of workforce that got bigger increases.
- The amount of the impact on the construction schedule, budget, profitability, and quality.
- The severity of the impact of labor shortage and losing loyal skilled workers.
- The implementation of the escalation clauses to adjust the contract's prices and durations.
- The adjustments by the estimating department to raise the cost of material and labor in their estimating data basis.
- Did competing firms adjust their prices in response to these forces?

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important to ensure that the duration of answering the survey was less than 10 minutes to facilitate responding to our voluntary survey. The authors eliminated time consuming questions and fill-in questions and combined questions to reduce the survey duration. Then the authors piloted the survey to assess its duration and to ensure that the subject interpreted the questions according to the intended meaning. Based on the provided feedback, the authors modified the survey instrument; the final survey instrument is included in Appendix I. Because this research involves human subjects, the Institutional Review Board (IRB) at Bowling Green State University reviewed and approved the survey prior to its distribution. The researcher used Qualtrics XM platform to create, distribute, and analyze the survey.

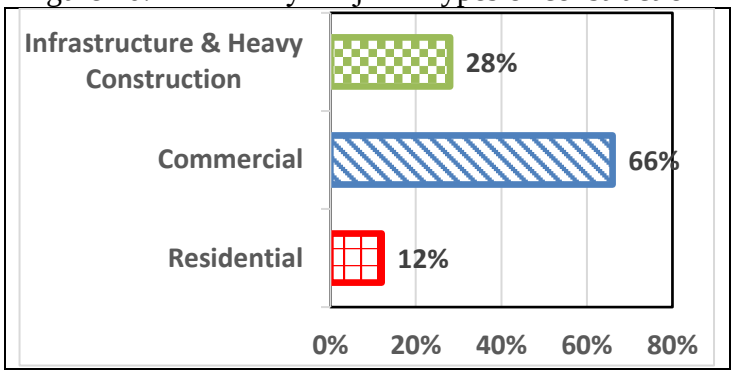
The construction management department in BGSU (CMD) has a cooperative education program (Coop) with well-established relationships with the construction industry. The authors used the Coop database after filtering it to remove unsuitable potential subjects such as the human resources personnel. The students of the CMD must take three coop classes (under the supervision of a faculty member) to graduate. The faculty member interview the students and their supervisors. If the supervisor was a suitable subject for the survey topic, the first author personally sought their help to make the research more meaningful and useful by participation. Most of the subjects were graduates of the CMD and knew the author personally, and they operated in Ohio and the neighboring states. The author also reached out to his personal construction contact and his LinkedIn contacts inviting them to answer the survey. At least 1100 construction professionals operating in the US were invited to respond to the survey. In the end, the survey got 109 valid responses despite all the efforts to increase the response rate constituting a response rate of 10%

Survey Results and Finding

Demographics of the Survey Subjects

Almost all the respondents worked for general contracting firms, but some of their firms can be a subcontractor occasionally. The respondents were either Project Manager, Construction Manager, or Estimator. These subjects has much more intimate knowledge and experience in dealing with supply chain disruptions and inflation.

Figure 10. The survey subjects' types of construction



The firms (for which the subjects were working) were involved in variety of types of construction; their distributions (which is shown in Figure 10) were as follow: 12% of the respondents engaged in residential construction, 66% were involved in commercial construction, 28% engaged in heavy construction (such as infrastructure and roads and bridges). Total is 106% not 100% because some firms engaged in more than one type of construction

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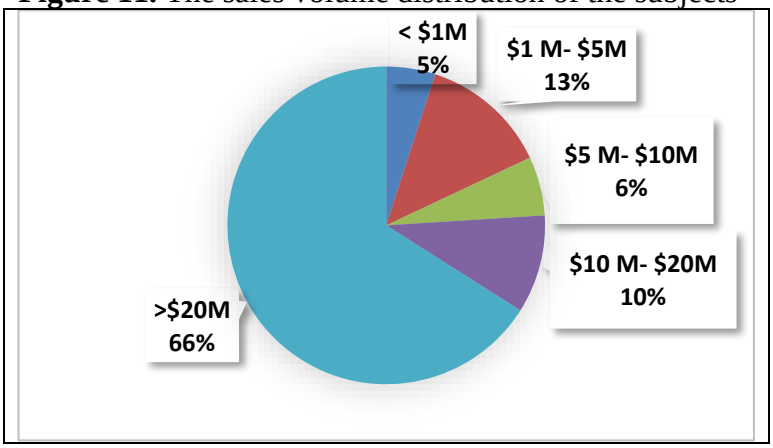
s volume distribution of the respondents is shown in Figure 11. 66% of respondents have an annual sales volume that exceeds $20 M; this may have skewed the subjects towards the larger side of firms. 10% of the respondents worked for firms with an annual sales volume between $10 and $20 M, 6% with an annual sales volume between $5 and $10 M, 13% with an annual sales volume between $1 and $5 M, and 5% with an annual sales volume less than $1 M.

Figure 11. The sales volume distribution of the subjects



The impact of materials /systems shortage on the business operations

The survey subjects rated the impact of the shortage of the materials /systems (listed in Table 2) on their business on a scale of 1 (almost no impact) -5 (very severe impact) (in case the material not applicable to company work keep blank). The authors used the Likert scale, or rating system, which is a measurement method used in research to evaluate attitudes, opinions, and perceptions (Qualtrics XM, 2024). In this analysis, the authors used a weight of one for minimum impact and five for maximum impact.

Figure 12 presents the impact of materials /systems shortage on the business operations of the subjects on a scale of 1 to 5. Most of the impacts were between 2.16 and 3, which means that the subjects did not significantly encounter shortage in these items because the encounter was either short in duration/magnitude, and/or the encounter was easily managed. Only pipe shortage had high impact of 4.0. It was hypothesized that long lead items that are manufactured to order (such HVAC, plumbing, and electrical fixtures), but the impact of their shortage were slightly above 2.5 (between 2.5 and 3).

The impact labor shortage on the business operations

In their answer to question # 6, how much did your firm increase the wages of its workers during the last 18 months; 17% of the respondents increased the wages of their workers by less than 5%, 52% increased them by 5 to 10%, 29% increase them by 10% to 20%, and only 2% had to increase their wages by more than 20%. Question #7 asked the subject what category of workers got higher wage raises? 29% of the firms increased the wages of the low skilled workers, 56% increased those of the middle-level-skilled-workers, and 60% increased the wages of the highly skilled workers. The total exceeds 100% because some firm increased more than one group.

The impact of supply chain disruptions on their construction projects

In their response to question #9- please indicate, where applicable, the percentage impact of supply chain disruptions on your construction projects, where 0 – 20% indicates the least impact with 81-100% the highest impact; the analysis results (using the Likert scale) are shown in Figure 13. The figures in the table indicate that

- labor shortage and inflation had a high impact (3.74 and 3.51 respectively),
- project schedule and losing good loyal skilled workers has a slightly above average impact, and profitability, substituting material and systems suffered low to no impact.

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Figure 12. Weight Value for the Impact of Shortage of Construction Material/Systems on their Operations

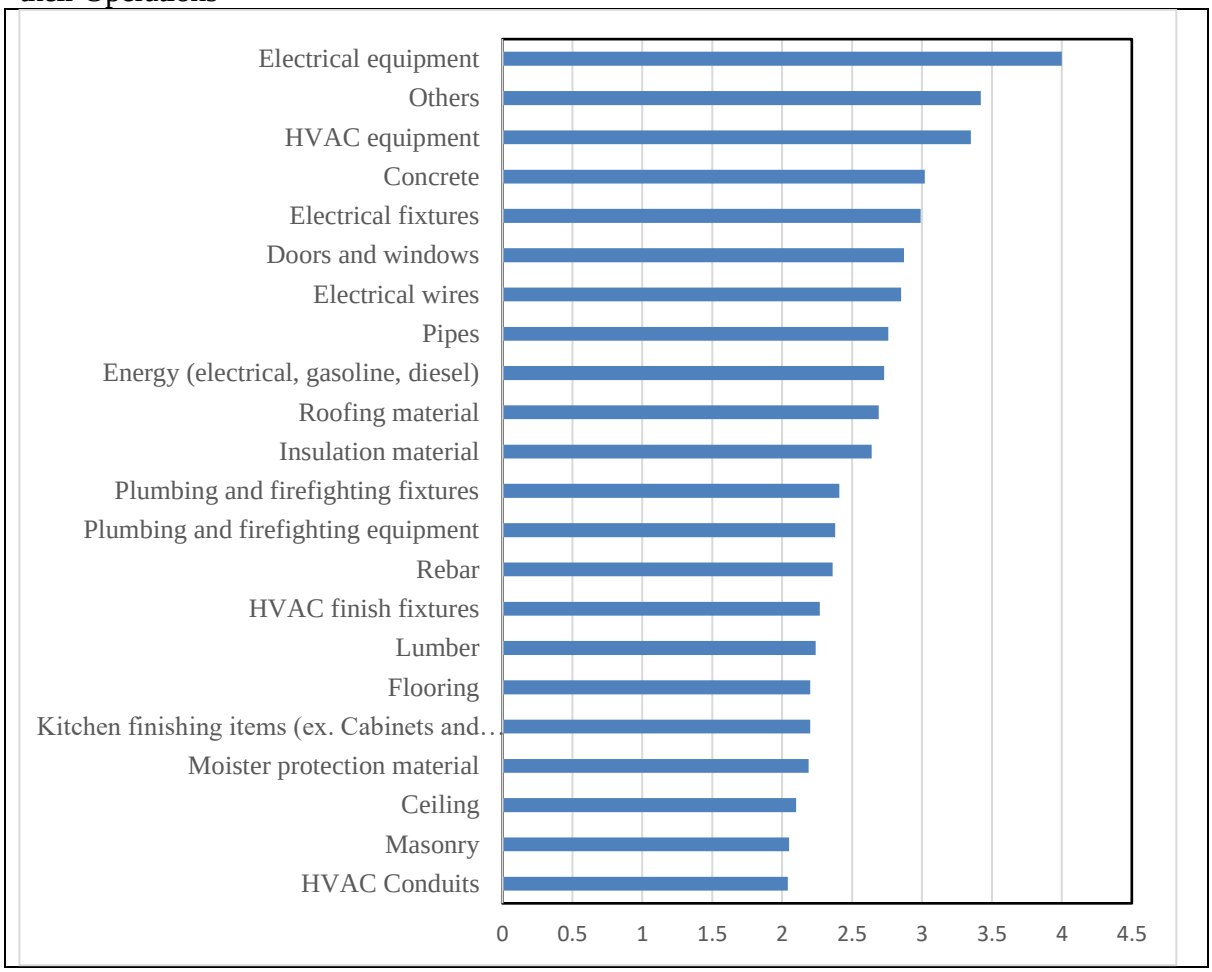
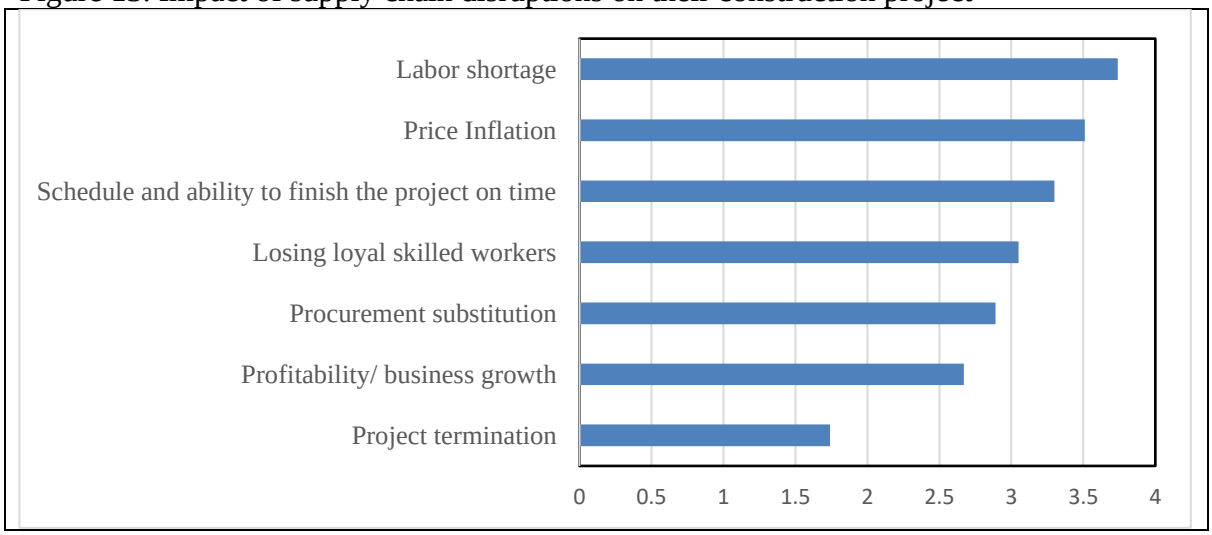


Figure 13. Impact of supply chain disruptions on their construction project



Employment of escalation clauses to adjust the contract price and duration.

In their response to question #10-If your firm suffered from inflated prices and supply chain problems, did the project owners consider it as part of the contracting business risks that the contractor must absorb or did the owners modify the contract price/duration? 40% of the project owners considered the inflation and supply chain problems as integral part of the

ing business risks that the contractor must absorb; on the other hand, 60% of the owners saw them as legitimate reasons for change order to modify the contract time and price. This may reduce (and partially explain) the impact of the supply chain disruptions and inflation on the construction operations of the research subjects.

Adjustment of the prices in the estimating databases

The responses to question# 11 - Did the estimating department in your firm update its cost databases to reflect the increased prices and material shortage? 98% stated that their estimating department updated their cost databases to reflect the increased prices and material shortage, and only 2% did not.

Question #12 - Did the competing firms (to your firm) update their prices to reflect the increased prices and material shortage? 92% of the respondents indicated that their competition increased their prices as well, and 8% did not see the competition raising their prices.

Future forecast

Question #13 asked the respondents when they foresaw that supply chain disruptions would subside? 20% of the subject saw improvement by the end of 2024, 22% saw improvement by the end of 2025, 53% of the subjects think it will never end; this is the new normal.

Question #14 asked the respondents how they foresaw the effects of the supply chain disruptions on the growth projections of their firms over the next three years. 22% expected a decline in the company's growth over the next 3 years, 34% expected that their company would maintain the same growth rate, and 45% expected that their firms would expand in the next three years due to the increased demand for their services.

Research Conclusion and Recommendation

The political and economic events during most of the 21st century drove the global central banks to keep interest rates low for a long time to avoid/reduce the impacts of economic recessions. During the second half of 2022, inflation started to rise due to the economic recovery from COVID 19, but global central banks assumed it to be a transitory inflation and underestimated its sticky nature. These banks started to raise interest rate to slow down the economy around March of 2023 which is about six months late. The Ukraine war at the beginning of 2023 added fuel to the inflationary drivers. Both COVID 19 and Ukraine war presented a significant challenge to the global supply chain including the construction material, equipment, and systems.

The research indicates that the construction industry in the US (and more accurately in Ohio) were able to absorb the supply chain disruptions and the inflationary pressure. The construction sector, which is a sizable portion of the GDP of the US economy, dealt with/managed the global supply chain distributions and inflation as hypothesized. The impacts of materials /systems shortages on the business operations of the survey respondents were slightly above average except for a few items; which means that the subjects encountered mostly minor shortage in these items, or the shortage lasted for a short manageable period. Shortage of pipes and HVAC equipment had a higher impact because typically they are manufactured after the client order them.

The US construction contractors increased the wages of their workers by 5%-20% during the research period. The wages of the skilled worker were raised by a higher percentage than the wages of low skilled workers as expected.

The supply chain disturbance, labor shortage, and inflation had some impact on the construction operations such as schedule and ability to finish the project on time. The impacts

shortage and inflation had a slightly above average impact (3.74 and 3.51 respectively). 60% of the project owners understood the inflation and supply chain problems as legitimate reasons for change order to modify the contract time and price. These owners' understanding of these force and cooperation to adjust the contract prices may have contributed to the low impact.

98% of the subjects stated that their estimating department updated its cost databases to reflect the increased prices and material shortage without affecting their competitive positions because their competition adjusted their prices in their database as well. 53 % of the respondents foresaw that current prices and inflation will never end; this is the new normal, and the other 47% saw these pressures easing by the end of 2024 or 2025. 34% of the respondents expected that their company would maintain the same growth rate, and 45% expected that their firms would expand in the next three years due to the increased demand for their services.

Research Recommendations

The authors assumed the respondents are a reasonable representative sample of construction industry in the US. However, most of the respondents were operating in the Ohio and its surrounding states, which might not be identical to other areas in the US. The authors recommend studying the effect of supply chain disruptions and inflation with respondents who work and operate in other parts of the US.

The subjects of this research were construction professionals working for contracting firms; it would be interesting to investigate the impact of supply chain disruptions and inflation from the perspectives of the project owners and architects/engineers. It is also recommended to study the effect of supply chain disruptions and inflation on the construction industry in other parts of the world specially in less economically fortunate countries because they may not have the capacity to deal with these issues.

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Appendix 1. Impact of Supply chain disruptions and Inflation on the Construction Industry

This is an informed consent for the "Effect of supply chain disruptions and inflation on the construction industry."

My name is Alan Atalah, and I am a professor at Bowling Green State University in the Construction Management Department. We are trying to study the impact of supply chain disruptions and inflation on the construction industry. We are approaching you because you are a construction professional whose experience and views are relevant to this study.

This research can help the construction industry by (1) evaluating the impact of supply chain disruptions and inflation (that the entire world experienced in 2022 and 2023) on the construction industry and (2) learning how the industry adjusted to the material shortage and inflation challenges. This is a voluntary survey without direct benefits.

We understand how busy construction professionals like you are; we deeply appreciate giving us an estimated to be less than 10 minutes of your time. After the completion of the survey, the collected data will be stored on a BGSU server. The collected data will be analyzed under my supervision to draw the appropriate databased conclusion. The risks involved in participation are no greater than those experienced in daily life.

Your participation is completely voluntary. You are free to withdraw at any time. You may decide to skip questions (or not do a particular task) or discontinue participation at any time without explanation or penalty. Your decision whether to participate will not affect your relationship with Bowling Green State University or with me. Please be advised that taking the survey indicates consent.

The survey data will be kept confidential and stored on a secured university server accessible only by me (and my graduate assistant Walid Al Azanki) with the appropriate password. The data will be kept for a year after the publication of the paper/report. This survey does not collect sensitive data; however, if you are concerned, please be aware that (1) some employers may use tracking software so you may want to complete the survey on a personal computer, (2) do not leave the survey open if using a public computer or a computer that others may have access to, and (3) clear your browser cache and page history after completing the survey.

If you have any questions, please do not hesitate to contact Professor Alan Atalah at aatalah@bgsu.edu or phone number: +(1) 419372 8354. If you have any questions about your rights as a participant in this research, please contact the Chair of the Institutional Review Board at Bowling Green State University, at +(1) 419-372-7716 or irb@bgsu.edu. Thank you for your time.

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Effect of Supply chain disruptions and Inflation on the Construction Industry.

3. What is the major type of construction work that your firm is involved in

☐ Residential ☐ Commercial ☐ Infrastructure and Heavy Construction

4. What is the annual sales volume for your firm?

☐ < $1M ☐ $1-$5M ☐ $5-10M ☐ $10-20M ☐ >$20

5. Please rate the impact of the shortage of these materials /systems on your business on a scale of 1 (almost no impact) -5 (very severe impact)

Material	**1 (min. impact)**	**2**	**3**	**4**	**5 (very severe impact)**
Lumber					
Concrete					
Rebar					
Energy (electrical, gasoline, diesel)					
Masonry					
Flooring					
Ceiling					
Roofing material					
Insulation material					
Electrical wires					
Electrical fixtures					
Electrical equipment					
Pipes					
Plumbing and firefighting fixtures					
Plumbing and firefighting equipment					
HVAC Conduits					
HVAC finish fixtures					
HVAC equipment					
Doors and windows					
Moister protection material					
Kitchen finishing items (ex. Cabinets and counters)					

Other (please state in the line below)

_____

6. If so, by how much on average did your firm have to increase the wages of your workers during the last 18 months?

   ☐ <0% ☐ 1-5% ☐ 5-10% ☐ 10-20% ☐ >20%

7. What type of labor shortage did your firm suffer?

   ☐ No shortage ☐ Low skilled workers ☐ Highly skilled workers

8. What category of workers got higher wage raises?

   ☐ Low skilled workers ☐ Middle level skilled workers ☐ Highly skilled workers

9. Using the table below, please indicate, where applicable, the percentage impact of supply chain disruptions on your construction projects, where 0 – 20% indicates the least impact with 81-100% the highest impact.

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RANGE OF IMPACT (%)	0-20 %	21-40 %	41-60 %	61-80 %	81-100 %
Schedule and ability to finish the project on time	☐	☐	☐	☐	☐
Price Inflation	☐	☐	☐	☐	☐
Profitability/ business growth	☐	☐	☐	☐	☐
Labor shortage	☐	☐	☐	☐	☐
Losing loyal skilled workers	☐	☐	☐	☐	☐
Procurement substitution	☐	☐	☐	☐	☐
Project termination	☐	☐	☐	☐	☐

10. If your firm suffered from inflated prices and supply chain problems, did the project owner consider it as
    - ☐ Part of the contracting business risks that the contractor must absorb
    - ☐ Legitimate reason for a change order to modify the contract time and price.
11. Did your estimating department update its cost to reflect the increased prices and material shortage?
    ☐ Yes ☐ No
12. If your estimating department updated its cost to reflect the increased prices and material shortage, did the cost update affect your competitive situation relevant to your competition?
    ☐ Yes ☐ No because my competition had to update their prices as well.
13. Do you foresee that supply chain disruptions will subside by
    ☐ The end of 2023 ☐ The end of 2024 ☐ The end of 2025 ☐ It will never end; this is the new normal.
14. Did the supply chain disruptions affect your firm's growth projections for the next three years?
    - ☐ Yes, our growth declined slightly ☐ No, our growth stayed the same
    - ☐ No, our growth projection increased because this is high demand for our services.
15. If you are interested in getting a copy of the published paper/report, please provide your email address:_____