Perception of COVID-19 impacts on the construction industry over time

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Abstract: The emergence of COVID-19 has been changing in the world since 2020 and prompted social, cultural, and economic systems to adjust their structures, routines, and processes. The economic aspects of the pandemic appeared soon, and many industries changed their workflow and procedures through a mandatory or recommended quarantine. Knowing the impact of COVID-19 on different areas of construction projects, concerns and considerations, and preparedness levels of corresponding entities helps construction managers to cope with the new situation. The main purpose of this study was to investigate the impact of COVID-19 on construction professionals’ perceptions over time. For this purpose, a longitudinal study was conducted to explore the perception of construction professionals toward COVID-19 impact and how it is changed over time. In this study, construction professionals from two countries with relatively similar timing for the pandemic outbreak participated in three rounds of surveys conducted six months apart. A total of 567 responses were collected, and statistical tests were conducted to examine the frequency and intensity level of COVID-19 impact as well as similarities and differences between different rounds. The novelty of this study is the exploration of the pandemic impacts over time and the exhibition of perception’s evolution. The statistical analyses showed a significant change in the perception of professionals in both regions. The results indicated a high level of COVID-19 impact on various construction aspects. The results also emphasized that the preparedness of related entities should be improved to manage raised concerns at different scales of construction professions.

Subjects: General Engineering Education; Engineering Economics; Construction Economics; Construction Management; ConstructionBusiness Management

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Dr. Rokooei's primary research interests include simulation and serious games, project management methodologies, construction education, data analytics, creativity and innovation, and emerging technologies. Dr. Rokooei is actively pursuing the development of educational techniques and methods in construction education. His research is formed around humans as the focal point in construction education and research. Aligned with his research agenda, the current study explored the interaction of construction professionals with COVID-19-related impacting factors in a volatile environment at the organizational level.

PUBLIC INTEREST STATEMENT

In this study, construction professionals participated in three rounds of surveys conducted six months apart. The main objective of this study was to understand the perceptions of construction professionals toward the COVID-19 impact. In addition, the second objective of this study was to show the similarities and differences of perceptions among different points of time. In this study, construction professionals with relatively similar timing for the pandemic outbreak participated in three rounds of surveys conducted six months apart. A total of 567 responses were collected, and statistical tests were conducted to examine the frequency and intensity level of COVID-19 impact as well as similarities and differences between different rounds.
Keywords: COVID-19; pandemics; construction industry; impact; perception

1. Introduction
The advent of COVID-19 was not far from its global contagion. Many countries became the target of this novel type of Coronavirus, and millions of people were contracted in a short period (Bong et al., 2020; Chowdhury et al., 2020). The severity of the condition forced official entities to make plans and take proper actions quickly (Ogunnusi et al., 2020). These activities were not limited to medical emergencies (Imani-Saber et al., 2020). Indeed, COVID-19 impacted numerous industries and sectors, among which the construction industry was uniquely different. The country’s economy, size, type of activities, interactions, sub-sectors, production time, and diversity were some factors that particularly affected the received impact and corresponding response of the construction industry (Gamil & Alhagar, 2020). Regarding these factors, the challenges created in construction projects should not be underestimated (Amoah & Simpeh, 2020). Also, the risks and adverse effects of the COVID-19 pandemic on tunnel construction sites were evaluated by Zhimin et al., providing the possible responses for the management of tunnel construction projects in China (Wang et al., 2020). Furthermore, the effects of the COVID-19 pandemic on construction stakeholders such as managers, engineers, and suppliers were assessed in interview-based work (Araya & Sierra, 2021). To have a rapid reaction to the construction sector’s short- and long-term impacts, guidelines are needed for the researchers and practitioners (Assaad & El-adaway, 2021). However, building models to investigate the spread of new Coronavirus on construction sites can be beneficial alongside the guidelines considerations (Araya, 2021).

In this situation, it is quite beneficial for construction managers to have a clear understanding of construction professionals’ perceptions toward the pandemic and its impact on their performance. The current study explores this impact and furnishes a cross-sectional and longitudinal overview of the situation in the expanding stages of the pandemic. For this purpose, a study was designed to investigate the collective perception of construction professionals toward COVID-19 over time. Meanwhile, it is seen that the construction industry in developed and developing countries has been differently adapted to new trends such as globalization, emerging technologies, and sustainability (Ofori, 2007). The main elements of the construction industry, including project management and performance, industry structure, and industry culture, are different in developed and developing countries (Ofori, 2007). Therefore, industry professionals in developed and developing countries may perceive the impact of the pandemic dissimilarly. However, due to confounding factors involved, location-based comparisons were determined out of scope in this study. This study did not aim to promote or demote any location concerning COVID-19 related actions or impact in construction. The results and their interpretations were provided in the results, discussion, and conclusion sections. This study contributes to the body of knowledge by providing an assessment of construction professionals’ perceptions about the impacts of COVID-19 on different aspects of construction organizations, projects, and individuals. It also highlights the evolution of professionals’ opinions over time and indicates the importance of construction’s agile models to manage unforeseen events such as pandemics.

2. Adverse impacts of COVID-19 on the construction industry
The virus pandemic has had considerable adverse effects on the global economy. International Monetary Fund (IMF, 2020) anticipated that the world would face sharply negative economic growth in 2020, with 6.1 and 1.0 percent decline in developed and developing economies, respectively. A 3.0 percent decrease in the world output rate is almost four times worse than the 2008 Global Financial Crisis (Lochmann, 2020). Regarding the report of the International Labour Organization (ILO), it was estimated that approximately 130 million full-time jobs would face
fallout in working hours in the first quarter of 2020, in which Americas (the continents of North and South America) act as the leader (Holshue et al., 2020).

The emergence of the COVID-19 crisis forced the governments to make attempts to advocate the jobs which are more vulnerable to lockdown consequences, especially self-employment jobs. These supports included financial aids (mostly gratuitous), tax deferrals, and food supply. For instance, in Europe, the European Investment Bank advocated the eligible governments by providing 3.2 trillion Euros ($3.5 trillion), the most massive amount of financial support among all countries over the world (CDC, 2020c; Robin, 2020), as a fiscal package to fight COVID-19. Moreover, the European governments allocated impressive budgets to compensate for job losses and bankruptcies in response to the chaos. Germany, Italy, Spain, and France allocated, as a direct fiscal impulse, 156 billion (Lachmann, 2020), 25 billion (Holshue et al., 2020), 200 billion (Robin, 2020), and 45 billion Euros (Lachmann, 2020), respectively. Also, the U.S. relieved 2.2 trillion dollars to slacken the virus pandemic and boost the U.S. economy, which is approximately 10 percent of Gross Domestic Product (GDP; Holshue et al., 2020). Furthermore, in the Middle East, the Iranian government allocated 20 percent of the annual budget of the state, i.e., 1,000 trillion rials (Robin, 2020).

The construction as one of the largest industries, directly and indirectly, influences the economy (Lachmann, 2020). This industry plays a crucial role in flourishing many jobs because of their independence, causing not being survived as the construction process stops working. In Australia and the U.K., the construction industry is responsible for almost 7% of the country’s GDP (Holshue et al., 2020). As a result, the more caring about the construction promotion, the less unemployment rate. Due to its importance, this issue not only handles the job incomes in urban areas but also controls the rural wages, because of the workers’ scarcity. For instance, India experienced a drastic drop in the number of immigrant workers before the widespread outbreak of the novel Coronavirus, which made a significant downfall in the development of construction projects (Robin, 2020). As shown in (Boseley, 2020), construction-related projects are classified in face-to-face works, and they cannot be implemented remotely. Therefore, some parts or all these kinds of projects may be stopped entirely when epidemics diseases occur. Moreover, a remarkable reduction will happen at the commencement of new construction projects (Lachmann, 2020). In the report published by the Australian Bureau of Statistics in 2010, in Australia, 22 percent of the new housing contract was felt down due to the 2008 Global Financial Crisis (Holshue et al., 2020).

It is undeniable that the injection of fiscal stimulus in the construction industry can be one of the first reactions that the governments take into consideration. In response to the 2008 Global Financial Crisis, the Australian Federal Government revealed 42 billion dollars (Boseley, 2020) for patronaging the construction projects, including schools, roads, and railways pushed the economy to grow 2.2 percent in 2010 (Lachmann, 2020). These kinds of financial supports help the companies in the building and construction supply chain prevent bankrupt. For instance, in 2013, Asgari investigated the effects of fiscal stimulus in compensating firms’ costs and project prices (Asgari, 2013). In this research, the author, by presenting a dynamic structural auction model, showed that the firms’ cost during the period of crisis could be diminished by 5.4 percent points (Holshue et al., 2020).

In addition to financial losses in construction companies, the outbreak of a contagious virus makes an unreliable space to attract foreign direct investment (FDI) for investing in the present or future construction projects. Appropriate strategies can increase the FDI flows in the economy, which makes the economic slowdown be faded and helps the rate of employment and job opportunities be promoted (Boseley, 2020). COVID-19 has shown a different behavior of spreading in any country. However, all the inferences are shaped based on the statistics daily revealed by the formal health agencies of the countries around the world. According to the economic expediencies and also ambiguous behavior of the novel Coronavirus, intentionally or unintentionally, these
statistics may be different from reality (Lachmann, 2020). Nevertheless, the scholars may not have any choices except to rely on these daily reports to analyze the virus’s demeanor.

Due to the COVID-19 pandemic, many construction projects were forced to stop by the governments (Ampornsah & Frimpong, 2020). In this situation, many big construction companies were faced fiscal losses. Small construction companies were also severely affected (Amoah et al., 2021). Early impacts of COVID-19 widespread on the U.S. construction industry were discussed in (Alshareef et al., 2021). As the situation is relaxing and the restrictions are gradually being lifted day by day, scholars are trying to find a way to increase the chance of returning to normal life. Furthermore, Jallow et al. showed that working remotely led the United Kingdom infrastructure sector to face difficulties in managing activities resulting in delays (Jallow et al., 2020). In 2021, Agyekum et al. found the “reduced work rate”, “delays in payments”, and “increase of material costs” as the major impacts of the pandemic on the construction projects in Ghana (Agyekum et al., 2021). Moreover, in research conducted in the United Arab Emirates (UAE) construction industry, it was proved that the government supports such as fee and fine waivers were quite critical for the construction companies to revive against pandemic (Rehman et al., 2021). These findings can be quite beneficial in prioritizing the available sources and developing action plans against the COVID-19 pandemic (King et al., 2021).

COVID-19 impacted the supply chain system as well. There are two classifications for the risk of the supply chain: operational and disruption risks (Chai et al., 2019; Ivanov, 2018, 2020; Xu et al., 2020). Although an operational risk deals with the disrupted internal processes and daily perturbations, a disruption risk mainly converses with the adverse effects of natural disasters and epidemic diseases (Ivanov, 2020). COVID-19 pandemic, as a disruption risk, created a tremendous supply shock in many countries developing a “supply chain contagion,” i.e., supply shock in all nations existing in the chain; however, some of them do not experience any disruption or less affected (Baldwin & Tomiura, 2020). This shock severely attacked both suppliers and demanders (Guerriero et al., 2020). Many established supply chains were drastically slowed down or even stopped. For instance, a gift operator company in Germany announced that it had faced remarkable supply shortages and demand disruptions because of COVID-19 (Ivanov, 2020). However, due to the rapid increase in particular chains, they were forced to grow quickly and build up new capacities (Baldwin & Tomiura, 2020). In this period, failure to provide medical supplies such as test kits, ventilators, masks, and personal protective equipment (PPE) could cause irreparable damage. For example, it was predicted that the U.S. would face the shortages of necessary medical equipment like ventilators regarding the rapid spread of the Coronavirus (Ronney et al., 2020). Furthermore, different supply chains may be intertwined in such a way that one’s hurt can lead to negative effects on the other. The coronavirus outbreak, and the decline in employment, have led to a significant reduction in the food supply chain, which in turn has resulted in widespread disruption in the labor supply chain, causing further job closures (Hobbs, 2020). In addition, Inoue and Todo showed that essential and non-essential production activities have considerable effects on a mega-city economy during the COVID-19 lockdown by presenting a simulation-based model (Inoue & Todo, 2020). Past research explored the impacts of the COVID-19 on different aspects of the construction industry during a limited period of time. Although COVID-19’s emerged as new phenomena with unknown impacts on the construction industry, over time, construction practitioners discovered different aspects of its impacts and gradually adjusted their way of work. Analyzing the way that the construction industry has evolved and reacted to the pandemic over time can help construction managers in adopting proper policy and mitigation strategies in possible similar situations.

3. Research design

Since different countries took different approaches to handle the pandemic, it was determined to explore the impact of COVID-19 in more than one location. Subsequently, two different countries
(U.S. and Iran) that have different social and economic conditions were selected. The timing of the COVID-19 outbreak was pretty similar in both countries. This trend helped to improve the inclusion aspects of the study and highlight similarities and differences between different rounds in the two country types. First, reported impacts of COVID-19 on the construction industry were reviewed. Then, a survey study was designed to investigate the perception of construction professionals at different points in time. A quantitative data collection method was used to capture construction professionals’ perceptions on topics related to the COVID-19 impact on construction. An identical survey was distributed to the same list of participants on three different occasions (i.e., April 2020, October 2020, and April 2021).

The primary purpose of this study was to understand how construction professionals perceived the COVID-19 impact on construction at different points in time and to what extent these perceptions have evolved. Obtaining the collective perception of the construction professionals in early pandemic time provides an informative input for construction managers in the design and implementation of response plans. This perception can be analyzed from different perspectives. First, expert judgment per se is crucial in the planning process. Construction professionals are a central component of the construction system, and their perceptions play an important role. Second, the generality of perceptions reveals global and regional aspects of impacts. Comparing perceptions of professionals based on their locations underscore similarities and differences that can be incorporated in the response model. Third, perceptions of professionals at a certain point of time during an evolving situation, like a pandemic, act as a milestone for further comparisons. The time-series exploration shows to what extent perceptions of professionals are changed and how they relate to reality. Therefore, it is required to collect data on the perceptions of participants at different points of time. To conduct this study, two countries of U.S. and Iran with distinct characteristics in the construction industry were selected. The study population comprised U.S. and Iran professionals in the construction industry with a full-time position, which statistically made an unlimited population size.

To practically obtain an acceptable set of subjects, the expected sample size was calculated based on the confidence interval of 95% \((Za/2 = 1.96)\) and the margin of error of 10% \((\varepsilon = .10)\), as well as the maximum proportion of respondents \((p = 50\%)\). The sample size was determined to have 97 subjects. A survey was designed for the target group to obtain quantitative data. The survey was developed as an instrument to collect descriptive quantitative data. Throughout the survey design process, and to ensure the validity and reliability of the survey scale, the 8-step DeVellis model was utilized. A list of COVID-19 impacts was developed through the literature review process in which all potential impacts were obtained, compared, and organized. A cross-sectional approach was employed to capture the information of the target sample at a single specific point in time. After sending the participation invite, 258 and 309 responses from the U.S. and Iran were collected, respectively, in three different rounds. Different statistical tests, including descriptive and Kruskal-Wallis H, were utilized to describe the data and measure the strength of association between variables. Also, Cronbach’s alpha measurement was used to examine the consistency and reliability of the survey. A Cronbach’s alpha of .864 was obtained from the overall analysis of the data, which is considered “high” for the internal consistency of the survey (Taber, 2017).

4. Results
The first round of the survey was distributed in the first week of April 2020. A survey link was sent to possible participants in both countries. Participants in the U.S. were identified through the corresponding author’s program industry advisory board as well as state professional organizations such as Associated Builders and Contractors (ABC) and Associated General Contractors of America (AGC). Construction professionals in Iran were approached through the co-author’s program industry group and national building organization. The survey was available for ten
days and, after the initial quality screening for completeness, all viable data were used in the data model (Round 1: R1). The next rounds of the survey were sent to the same participants in Oct. 2020 (Round 2: R2) and April 2021 (Round 3: R3). Table 1 provides the demographic information of participants:

In the following figures and paragraphs, Group A and B represent the participants who were working in the U.S. and Iran construction companies, respectively. To explore the immediate impact of COVID-19, participants were asked if their working time was impacted. While the majority of Group A stated that their working time was not changed, the vast majority of Group B reported that their working time was decreased. However, this considerable difference was reduced in the following rounds. The percentage of each alternative is shown in Figure 1.

Participants were asked to what extent their current responsibilities/jobs could be accomplished remotely/online at the time of responding to the survey, using a 5-level Likert scale (1: Very Low, 5: Very High). The weighted average of each round for both groups is shown in Figure 2. Participants in Group A stated that their responsibilities could be done remotely with an above-average score in the first round, but this number decreased in the next rounds. Conversely, the weighted average scores of Group B increased over time.

In the next section, participants were asked to rate to what extent they had proper Software/Procedures/Guidelines and Hardware/Equipment to do their job remotely/online, using a 5-level Likert scale (1: Very Low, 5: Very High). Figure 3 shows the weighted average of responses in three rounds for both groups. In all three rounds and in both software and hardware areas, the weighted average of scores in Group A was higher than that of group B; however, statistically, there was no meaningful difference between rounds in either group.

The magnitude of COVID-19 impact on construction was the subject of the next question. In this section, participants were asked to rate to what extent they believed that COVID-19 generally impacted the construction industry, using a 5-level Likert scale (1: Very Low, 5: Very High). The weighted average of scores in group A was 3.65, 3.4, and 3.6 (out of 5) in rounds 1 to 3,

| Table 1. Demographic information |
|----------------------------------|
| (a) Gender (%) | Female | Male |
| Group A | 17 | 83 |
| Group B | 8 | 92 |
| (a) Age—years (%) | Under 26 | 26–35 | 36–45 | 46–55 | 56+ |
| Group A | 1 | 13 | 27 | 23 | 36 |
| Group B | 0 | 38 | 42 | 17 | 3 |
| (a) Experience—years (%) | < 3 | 3–7 | 8–15 | 16–25 | 25+ |
| Group A | 1 | 7 | 15 | 22 | 55 |
| Group B | 1 | 20 | 34 | 34 | 11 |
| (a) Position (%) | Project Manager | H.R. Manager/Agent | Technical Manager | Field/Tech. Engineer | Others |
| Group A | 33 | 5 | 2 | 0 | 60 |
| Group B | 47 | 6 | 10 | 27 | 10 |
respectively, while these numbers were 4.08, 3.46, and 3.38 (out of 5) in Group B. The weighted average score of the impact level for each round is shown in Figure 4.

In addition to descriptive analyses, correlation analyses were used to evaluate the strength of the relationship between quantitative variables. For this set of analyses, the time (round) was
considered an independent variable that could associate with other ordinal variables derived from the Likert scale. The independent variable is dichotomous, which lays a foundation for the Kruskal-Wallis H test to compare groups on different aspects. For these tests, the required assumptions were reviewed. The dependent variables were measured at an ordinal level or above. The independent variable (time) consisted of two or more categorical independent groups. There was no relationship between the observations in each group or between the groups themselves to provide independence of observations. Also, the distribution of scores for each group of the independent variable had the same shape. A Kruskal-Wallis H test showed that there was not any statistically significant difference in impact score between the different rounds in Group A, Kruskal-Wallis H = 3.775, p = 0.151. The same procedure was repeated for Group B, in which the Kruskal-Wallis H test showed that there was a statistically significant difference in impact score between the different rounds, Kruskal-Wallis H = 36.837, p = 0.000, with a mean rank impact score of 181.91 for R1, 126.29 for R2, and 121.34 for R3. Also, post hoc tests were conducted to test pairwise comparisons. Dunn-Bonferroni post hoc method showed that the first round (R1) was significantly different from R2 and R3 (p = 0.000).

In the next section, participants rated the impact of COVID-19 on different aspects of their projects or organizations to the response date, using a 5-Level Likert scale (1: Very Low, 5: Very High). The evaluated areas included the following items. Table 2 shows the weighted average score of each item, out of 5, rated by both groups in April 2020 (R1). The average of all weighted average scores in Group A was 2.98 (out of 5), while this number in Group B was 3.56 (out of 5). The minimum and maximum (Min, Max) of weighted average scores in groups A and B were (2.16, 3.88) and (3.06, 4.15), respectively.

1. Availability of competent employees to hire
2. Shortage of construction materials
3. Availability of construction equipment (for renting/leasing)
4. Employees’ health and safety
5. Employees productivity due to the anxiety
6. Amount of projects’ overhead costs
7. Your company’s profit
8. Your company safety regulations and guideline
9. Keeping the same number of clients and projects
Table 2. The weighted average of items (a1-a13) in April 2020

| Group | a1  | a2  | a3  | a4  | a5  | a6  | a7  | a8  | a9  | a10 | a11 | a12 | a13 |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| A     | 2.6 | 2.55| 2.18| 3.69| 3.06| 3.12| 3.05| 3.88| 3.11| 3.24| 2.16| 3.21| 2.93|
| B     | 3.06| 3.27| 3.17| 4.15| 3.8 | 3.58| 3.48| 3.52| 3.28| 3.54| 3.73| 4.04| 3.73|
(10) Local government shutdown
(11) International projects/imports/travels
(12) Delivering projects on time
(13) Delivering projects on budget

Then, the difference between the weighted average score of each item in R2 and R1 and R3 and R2 was calculated, as shown in Equation 1 where $i = \text{score } (1-5), r = \text{round } (1, 2, 3)$.

$$\sum_{r=1}^{2} \left( \sum_{i=1}^{5} \frac{S_{ri}}{n_r} \right) \left( \frac{S_{ri}}{n_r} \right)$$

The number resulting from Equation 1 shows the average difference between the weighted average score of each consecutive pair of rounds. In other words, this number which has a range of $-4$ to $+4$, shows how participants perceived the status of each item compared to the previous round. Figure 5 shows the average difference for both groups.
In the next section, participants rated to what extent they believed each item or entity was prepared to handle the impact of COVID-19. The levels of preparedness were rated through a 5-level Likert scale in which 1–5 denoted the Very Low to Very High range. The rated entities (b1-b8) included the following items:

1. Your personal life
2. Your professional career
3. Your division/group/department
4. The organizational system in your company
5. The technical and procedures in your company
6. Your subcontractors
7. Your clients
8. The construction industry in general

In this set and as shown in Table 3, the average of all weighted average scores in Group A was 3.21 (out of 5), while this number in Group B was 2.92 (out of 5) in the first round (April 2020). The minimum and maximum (Min, Max) of weighted average scores in groups A and B were (3.0, 3.4) and (2.69, 3.29), respectively, in the same round.

Similar to the previous section, Equation 1 was used to explore the difference between the weighted average score of items in consecutive pairs of rounds in each group. Figure 6 shows the average difference for both groups.

The next section explored the intensity of construction professionals’ concerns during the COVID-19 era. These items included the following areas:

1. Handling issues related to family
2. Availability of personal protective equipment/material
3. Health concerns
4. Job stability
5. Changing the job routine (e.g., online work)
6. Changes in projects time/cost/scope/etc.

Participants rated these items using a 5-level Likert scale. In this section, the average of weighted average scores in Group A was 3.69 (out of 5), while Group B was 2.74 (out of 5) in the first round (R1). While two groups exhibited a similar trend in their concerns, the only anomaly was the concern pertaining to changes in project time/cost/scope, in which Group B rated that as the most important concern (Table 4).

| Group | b1 | b2 | b3 | b4 | b5 | b6 | b7 | b8 |
|-------|----|----|----|----|----|----|----|----|
| A     | 3.4| 3.24| 3.29| 3.26| 3.27| 3  | 3.13| 3.16|
| B     | 3.29| 3.04| 3.05| 2.94| 2.84| 2.69| 2.83| 2.7 |
Figure 6. Average scores difference rated items (b1-b8) by both groups.

The difference between the weighted average score of items in consecutive pairs of rounds in each group was calculated using Equation 1. Figure 7 shows the average difference for both groups.

In the final section, participants were asked to express how soon they believed the impact of COVID-19 on their projects would be removed entirely, and projects’ status would be back to the before COVID-19 time. Possible items included “within 1 month”, “within 3 months”, ‘within 6 months”, “within 1 year”, and “more than one year.” Both groups showed a very similar pattern in time intervals. Only one-eighth of participants in each group believed that the COVID-19 situation would last more than 1 year in April 2020 (R1), while this number in April 2021 (R3) changed to 63% and 30% in groups A and B, respectively. Figure 8 shows the percentage of rated periods for three rounds.

Possible associations between different rounds in each group were evaluated to explore changes in participants’ perceptions toward the COVID-19 diminishing time. In this section, the time (round) was considered an independent variable, and the perception, as an ordinal data type, was employed as the independent variable. Required assumptions to conduct the Kruskal-Wallis...
The assumptions included the ordinal or continuous level of the dependent variable, two or more categorical, independent groups forming the independent variable, independence of observations, and distribution homogeneity.

The Kruskal–Wallis H test showed that there was a statistically significant difference in normalcy time score between the different rounds in Group A, Kruskal–Wallis $H = 3.775$, $p = 0.151$ with a mean rank impact score of 92.99 for R1, 144.69 for R2, and 146.98 for R3. Also, post hoc tests were conducted to test pairwise comparisons. Dunn–Bonferroni post hoc method showed that the first round (R1) was significantly different from R2 and R3 ($p = 0.000$). A similar procedure was conducted for Group B. The Kruskal–Wallis H test showed that there was a statistically significant difference in impact score between the different rounds, Kruskal–Wallis $H = 122.78$, $p = 0.000$, with a mean rank impact score of 104.78 for R1, 205.86 for R2, and 220.42 for R3. Also, Dunn–Bonferroni post hoc method showed that the first round (R1) was significantly different from R2 and R3 ($p = 0.000$) in Group B.
5. Discussion
The emergence of COVID-19 abruptly changed the work routine in many industries. The COVID9-19 impact was not limited to medical areas, although the immediate cure of people who contracted the disease was the most urgent concern. The intensifying wave of COVID-19 impact then resonated with other business areas and crippled their economies. The construction industry, as a massive body with high inertia, was among industries that were hit by the pandemic with a delay. The current study aimed first to explore general perceptions of professionals about the impact of COVID-19 on the construction industry and then compare these perceptions at different points of time to draw how these perceptions have changed over time. Exhibiting converging and diverging traits between three rounds in two groups (Group A: U.S., Group B: Iran) helps construction organization managers to prepare more effective response plans, considering global and local aspects. In both groups, project managers comprised about 40% of participants, and the rest reported a different job position. This ratio provides a common ground for meaningful comparison through a project management lens. In the first section, a notable difference between the three rounds in the two groups was the reported change in working time. One explanation for this in group B with a high percentage of “decreased working time” is the centralized organizational system in which there is a high dependency on government, as in this case, in Iran, the government halted some construction-related activities. On the other hand, participants in Group A reported a higher percentage of “increased working time” in the following rounds, which can indicate extra time to catch up with delays caused by the pandemic.

The next noticeable point was the comparisons between the three rounds in having proper access to a) software and b) hardware to perform their jobs (Figure 3). The weighted average of all three rounds for both software and hardware in each group was similar, and there was no statistically significant difference between categories. However, Group B consistently reported a lower weighted average than Group A in all categories. Another visible note between the two groups was the rated level score. In almost all areas/items related to the impact of COVID-19, Group B showed a higher weighted average, which means a greater estimated impact (Table 2). In addition, in both groups, generally, the difference between the R1 and R2 was greater than the difference between R2 and R3 (Figure 5), and the majority of these differences were negative, meaning the average score of round 2 (R2) was lower than the average score of round 1 (R1). In other words, both groups initially had a perception about a larger impact on different aspects of the construction industry (a1-a13). A similar situation was observed in items related to professionals’ concerns during the COVID-19
era (Table 4 and Figure 7). Also, a reverse situation is reported about the preparedness level of different entities dealing with COVID-19 (Table 3 and Figure 6). The above sections can be explained as a descending trend in the perceived impact of COVID-19 over time, a descending trend in the level of concern, and an ascending trend in the level of preparedness. Another notable point, derived from Figure 8, is the wrong prediction of professionals about returning to normalcy. Only 12 and 13 percent of participants in Group A and Group b, respectively, predicted that it would take more than one year to get back to the “before-COVID-19” time in the first round, while these numbers have changed to 63% and 30%, respectively, in the third round.

6. Conclusion
This paper briefly reported the results of a study on the impact of COVID-19 on construction professionals’ perceptions in the U.S. and Iran. The main objective of this study was to understand the perceptions of construction professionals toward the COVID-19 impact. In addition, the second objective of this study was to show the similarities and differences of perceptions among different points of time. The findings help construction managers and policymakers to adopt global approaches when there is a relative consensus between groups and localize the response plans in case of divergence. The results indicated that, in general, both groups in three rounds perceived the impact of COVID-19 relatively high on various aspects of their professional careers. However, this perceived impact was lessened over time. Although different entities or areas were believed to bear different levels of impact, the was no comfort zone in the construction industry confronting COVID-19. This impact positively correlates with the economic status of society. Conversely, the perception toward the preparedness of individuals or entities to handle the pandemic impact was consistently reported higher in a more robust economy. Another noticeable outcome of the study was the spectrum of similarities and differences. The results showed that as the scale of area or item grows, similarities descend, and differences highlight. This fact emphasizes the role of systems and their interdependencies on perceived—and real—situations. Although the research design was performed as planned, there were some limitations that affected the process. One of the limitations was the number of participants. Although the received responses exceeded the required threshold, the higher number of participants could increase the reliability of the results. Another limitation of the study was the response intervals. Since each round represented a six-month period, any COVID-19 related event could change the perception within this period. However, it was assumed that the perceptions of professionals were proportionately reflected in each round. Despite the study’s results, the generalization of outcomes is not warranted in this study. While the three rounds of surveying in two groups exceeded the required number of responses, a larger sample size enhances the reliability of the analysis. In addition, conducting similar studies in other countries from developing and developed areas provides the opportunity for more robust comparisons. Further study will include further rounds of surveys to explore the change of perceptions at different points of time among construction professionals.

**Funding**
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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**Disclosure statement**
No potential conflict of interest was reported by the author(s).

**Data availability**
Some or all data, models, or codes that support the findings of this study are available from the corresponding author upon reasonable request.
Citation information
Cite this article as: Perception of COVID-19 impacts on the construction industry over time, Saeed Rokooei, Amin Alianchi & Mostafa Rahimi, Cogent Engineering (2022), 9: 2044575.

References
Agyeikum, K., Kukah, A. S., & Amudjie, J. (2021). The impact of COVID-19 on the construction industry in Ghana: The case of some selected firms. Journal of Engineering, Design and Technology, 201, 222–244. https://doi.org/10.1108/JEDT-11-2020-0476
Alsharif, A., Banerjee, S., Uddin, S. M., Albert, A., & Joselski, E. (2021). Early impacts of the COVID-19 pandemic on the United States construction industry. International Journal of Environmental Research and Public Health, 18 (4), 1559. https://doi.org/10.3390/ijerph18041559
Amoah, C., Barom-Agyei, E., & Simphe, F. (2021). The COVID-19 pandemic: The woes of small construction firms in Ghana. Smart and Sustainable Built Environment, ahead-of-print (ahead-of-print). 2046-6009. https://doi.org/10.1108/SSBE-02-2020-0025
Amoah, C., & Simphe, F. (2020). Implementation challenges of COVID-19 safety measures at construction sites in South Africa. Journal of Facilities Management, 19(1), 111–128. 1472-5967. https://doi.org/10.1108/JFM-08-2020-0061
Amoah, C., & Simphe, F. (2020). Implementation challenges of COVID-19 safety measures at construction sites in South Africa. Journal of Facilities Management.

Amponsah, R., & Frimpong, I. A. (2020). Ghana in the face of COVID-19: Economic impact of Coronavirus (2019-NCOV) outbreak on Ghana. Open Journal of Business and Management, 8(4), 1404. https://doi.org/10.4236/ojbm.2020.840889

Araya, F. (2021). Modeling the spread of COVID-19 on construction workers: An agent-based approach. Safety Science, 133, 105022. 925-7535. https://doi.org/10.1016/j.ssci.2020.105022

Araya, F., & Sierra, L. (2021). Influence between COVID-19 impacts and project stakeholders in chilean construction projects. Sustainability, 13(18), 10082. https://doi.org/10.3390/su131810082

Asgari, L. (2013). The effect of the 2008 economic crisis on construction procurements. University of Arizona, Eller College of Management, Department of Economics.

Assaad, R., & El-adaway, I. H. (2021). Guidelines for responding to COVID-19 pandemic: Best practices, impacts, and future research directions. Journal of Management in Engineering, 37(3), 06021001. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000906

Baldwin, R., & Tomiura, E. (2020). Thinking ahead about the trade impact of COVID-19. Economics in the Time of COVID-19, 59, 59–71. https://repository.gradauteinstitute.ch/record/298220/fn/en

Bong, C. L., Brasher, C., Chikumbu, E., McDougall, R., Mellin-Olsen, J., & Enright, A. (2020). The COVID-19 pandemic: Effects on low-and-middle-income countries. Anesthesia and Analgesia, 131(1), 86–92. https://doi.org/10.1213/ANE.00000000000010486

Boseley, S. (2020). Coronavirus causes mild disease in four in five patients, says WHO. The Guardian. https://www.theguardian.com/world/2020/feb/17/corona

References
Alvanchi (2022). Cite 2021 (1), 2020 (1), 2020 (3), 2020 (5), 2021 2018 - 2021.

Boseley, Bong, Allo, Amoah, Rokooei, al., 2022, Boseley, Bong, Amoah, Rokooei, al., 2022 (1804575).

Citation
2020. (2021). Public health screening to begin at 3 U.S. airports for 2019 novel coronavirus ("2019-nCoV"). The Centers for Disease Control and Prevention (CDC). https://www.cdc.gov/media/releases/2020/p0117-coronavirus-screening.html

Choi, T. M., Wen, X., Sun, X., & Chung, S. H. (2019). The mean-variance approach for global supply chain risk analysis with air logistic in the blockchain technology era. Transportation Research Part E: Logistics and Transportation Review, 127, 178–191 1366-5545. https://doi.org/10.1016/j.tre.2019.05.007

Chowdhury, R., Heng, K., Shawon, M. S. R., Goh, G., Okonofua, D., Ochoa-Rosales, C., Gonzalez-Jaramillo, V., Bhuiya, A., Reipath, D., Prathapan, S., Shahzad, S., Althaus, C. L., Gonzalez-Jaramillo, N., & Franco, O. H. (2020). Dynamic interventions to control COVID-19 pandemic: A multivariate prediction modelling study comparing 16 worldwide countries. European Journal of Epidemiology, 35(5), 389–399. https://doi.org/10.1007/s10654-020-00645-w

Gerpl, Y., & Alhagag, A. (2020). The impact of pandemic crisis on the survival of construction industry: A case of COVID-19. Mediterranean Journal of Social Sciences, 11(4), 122–122. https://doi.org/10.36941/mjss-2020-0067

Guerrieri, V., Lorenzoni, G., Straub, L., & Werning, I. (2020). Macroeconomic implications of COVID-19: Can negative supply shocks cause demand shortages? SSRN Electronic Journal (26918). https://doi.org/10.2139/ssrn.3570096

Hobbs, J. E. (2020). Food supply chains during the COVID-19 pandemic. Canadian Journal of Agricultural Economics/Revue Canadienne D’agroeconomie, 68(2), 171–176. https://doi.org/10.1111/cjag.12237

Holshue, M. L., DeBolt, C., Lindquist, S., Lofy, K. H., Wiesman, J., Bruce, H., Spitters, C., Ericson, K., Wilkerson, S., Turoll, A., Diaz, G., Cohn, A., Fox, L. A., Patel, A., Gerber, S. I., Kim, L., Tong, S., Lu, X., Lindstrom, S., … Pillai, S. K. (2020). First case of 2019 novel coronavirus in the United States. New England Journal of Medicine, 382(10), 929–936. https://doi.org/10.1056/NEJMoa2001191

Imani-Saber, Z., Vaseghi, H., Mohdian, M., Safari, F., & Ghadami, M. (2020). Variable clinical manifestations of COVID-19: Viral and human genomes talk. Iranian Journal of Allergy, Asthma and Immunology, 19(5), 456–470. https://doi.org/10.18502/ijaai.v19i5.4461

IMF. (2020). World economic outlook. International Monetary Fund. https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020

Inoue, H., & Todo, Y. (2020). The propagation of economic impacts through supply chains: The case of a mega-citv lockdown to prevent the spread of COVID-19. PloS one, 15(9), 1–10. https://doi.org/10.1371/journal.pone.0239251

Ivanov, D. (2018). Structural Dynamics and Resilience in Supply Chain Risk Management, 1, 0884–8289. Springer, Cham, XXIV, 320. https://doi.org/10.1007/978-3-319-69305-7

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. Transportation Research Part E: Logistics and Transportation Review,
Jallow, H., Renukappa, S., & Suresh, S. (2020). The impact of COVID-19 outbreak on United Kingdom infrastructure sector. Smart and Sustainable Built Environment, 10(4), 581–593. https://doi.org/10.1108/SASBE-05-2020-0068

King, S. S., Rahman, R. A., Fauzi, M. A., & Haron, A. T. (2021). Critical analysis of pandemic impact on AEC organizations: The COVID-19 case. Journal of Engineering, Design and Technology, 20(1), 245–266. https://doi.org/10.1108/JEDT-04-2020-0225

Lachmann, A. (2020). Correcting under-reported COVID-19 case numbers. MedRxiv, 1–5. https://doi.org/10.1101/2020.03.14.20036178

Ofori, G. (2007). Construction in developing countries. Construction Management and Economics, 25(1), 1–6. https://doi.org/10.1080/01446190601114134

Ogunnusi, M., Hamma-Adama, M., Salman, H., & Kouider, T. (2020). COVID-19 pandemic: The effects and prospects in the construction industry. International Journal of Real Estate Studies, 14(2), 120–128. https://rgu-repository.worktribe.com/output/1000407

Rabin, R. C. (2020). First patient with Wuhan coronavirus is identified in the U.S. The New York Times Company. https://www.nytimes.com/2020/01/21/health/cdc-coronavirus.html

Ranney, M. L., Griffith, V., & Jha, A. K. (2020). Critical supply shortages – The need for ventilators and personal protective equipment during the Covid-19 pandemic. New England Journal of Medicine, 382(18), e41. https://doi.org/10.1056/NEJMp2006141

Rehman, M. S. U., Shafiq, M. T., & Afzal, M. (2021). Impact of COVID-19 on project performance in the UAE construction industry. Journal of Engineering, Design and Technology, 20(1), 245–266. https://doi.org/10.1108/JEDT-12-2020-0481

Taber, K. S. (2017). The use of Cronbach’s Alpha when developing and reporting research instruments in science education. Res Sci Educ, 48, 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Wang, Z., Liu, Z., Liu, J., & Lei, M. (2020). Risk identification and responses of tunnel construction management during the COVID-19 pandemic. Advances in Civil Engineering, 2020, 1–10. https://doi.org/10.1155/2020/6620539

Xu, S., Zhang, X., Feng, L., & Yang, W. (2020). Disruption risks in supply chain management: A literature review based on bibliometric analysis. International Journal of Production Research, 58(11), 3508–3526. https://doi.org/10.1080/00207543.2020.1717011
