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Effect of the Covid-19 pandemic on the construction sector: A systematic literature review

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Effects of the COVID-19 pandemic on the construction sector: A systemized review

Abstract

Purpose: The COVID-19 pandemic has brought profound changes to all sectors of society including the construction sector. The main purpose of this study is to explore and provide insights into the impact and changes that have occurred in the construction sector due to COVID-19 and to present a mitigation framework to minimize the effects.

Design/methodology/approach: The scope of this study is limited to peer reviewed articles in Scopus or Web of Science indexed journals. A systemized review was performed with bibliometric and content analyses of articles related to the impact of COVID-19 on the construction sector.

Findings: Through content analysis, the main topics discussed in the selected articles were grouped into 10 categories. Most of these studies were found to have focused on the challenges, impact, and health and safety at construction sites resulting from the pandemic. The study further identified 39 sub-topics through detailed content analysis and organizes them into the categories of negative impacts, positive impacts and opportunities, and barriers to COVID-19 safety guidelines in the construction sector. Moreover, the study developed a systematic mitigation strategy based on the recommendations of the literature review to reduce the impact of the current pandemic on the construction sector. The mitigation strategy presents separate set of measures regarding safety guidelines, process improvements, government intervention, psychological support, and technology adoption.

Originality/Value: The research insights provided in this study are useful for practitioners in guiding them to design effective strategies for addressing the challenges of the COVID-19 pandemic and future crises. Furthermore, a systematic presentation of the impacts, challenges, and mitigation measures in this study will help researchers to identify existing gaps in the literature and explore other aspects of the impact of the pandemic on the construction sector.

Keywords: Challenges, Construction sector, COVID-19 pandemic, health and safety guidelines, Systemized review

1 Introduction

The COVID-19 pandemic has caused significant challenges. It has resulted in extraordinary restrictions on international trade, disrupted supply chains, increased unemployment, and slowed down global economic growth (Amponsah & Frimpong, 2020). The construction sector is no exception. The pandemic has severely affected this sector in an unprecedented manner (Alsharef et al., 2021) by posing

multi-faceted challenges such as legal and contractual complications (Ogunnusi et al., 2020), health and safety challenges (Amoah & Simpeh, 2020; Simpeh et al,, 2021), shortages of material and equipment (Alsharef et al., 2021), shortages of skilled labour (Sierra, 2021), project delays (Jallow et al., 2020), increased project costs, payment delays from sponsors (Sami Ur Rehman et al., 2021), and project suspensions (Agyekum et al., 2021; Alsharef et al., 2021).

These effects are especially damaging because the construction industry is a pillar of the economy (Ebekozien, 2020) and a vital engine of growth and development in many countries (Murie, 2007). Construction provides employment to 7 percent of the world population and accounts for 10 percent of gross domestic product (GDP) worldwide (International Labour Organization, 2017). The world, in particularly developing countries, cannot afford to close the construction sector for a long time during the current pandemic. Construction activities were resumed amidst the pandemic following the safety guidelines formulated by the World Health Organization (WHO) such as social distancing, wearing masks, and other health and hygiene guidelines (WHO, 2020).

The safety of the construction workforce was already a significant challenge due to manual handling of materials (Haslam et al., 2005), complex and difficult activities (Woolley, Goode, Salmon, & Read, 2020), the hazardous nature of the work (Haslam et al., 2005), working around confined spaces (Dutta et al., 2020), and the temporary nature of arrangements in the construction sector (Stiles et al., 2018). Other possible reasons for the poor safety record in the construction sector are disregard for the effect of safety on project success (Smallwood & Haupt, 2007), and the tug of war between safety and productivity in the sector (Damon, 2014). The estimates of the International Labour Organization (ILO) show that the construction sector is responsible for around 30 to 40 percent of total fatalities globally (ILO, 2017), which is considerably higher than its share in world employment.

This safety situation has been further exacerbated due to the challenges of COVID-19 (Araya, 2021). Labourers, foremen, technical staff, and supervisors need to work closely within a limited space with many nodes of activities concurrently. This proximity increases the possibility of transmission of communicable diseases including COVID-19 (Gan & Koh, 2021). The pandemic has forced the construction sector to face new challenges, new global scenarios, higher uncertainties, new opportunities, and requirements.

The high vulnerability of the construction sector to the current pandemic and its contribution to the economic development of countries have made the subject of interest to researchers around the world. Current research has investigated and analyzed the impacts and changes in the construction sector due to the COVID-19 pandemic from a number of perspectives. However, there has been little or no attempt to map this work to comprehend the findings and capture the trends in research that has potential implications for the sector. There has been one literature review study performed by Sierra (2021) related to challenges to contractors in United Kingdom (UK) during the COVID-19 pandemic. However, the study was of limited

scope and was mainly based on videos, magazine articles, and webinars related to the UK. Therefore, it did not fulfill the need for a comprehensive literature review paper related to the impact of the COVID-19 pandemic on the construction sector. To fill this gap, this study performed a detailed literature review of related peer reviewed articles published by the Web of Sciences or Scopus indexed journals. A comprehensive literature review is indispensable to assist stakeholders in understanding the international context and implications of COVID-19 on the construction sector and provide a comprehensive set of measures to mitigate the impacts of the current pandemic and other future crises.

The findings of this study are expected to be beneficial for practitioners in the construction sector in responding effectively to the current pandemic. The study will give a better understanding of the current situation and will help practitioners to make better informed decisions to reduce the current pandemic risk. The study will also provide a good understanding of the new literature and knowledge development in the construction sector related to responses to pandemics. Furthermore, it will help researchers to identify and fill the gap in the available literature and look for new aspects of the impact of COVID-19 on the construction sector.

The remainder of this paper is organized as follows. Section 2 discusses the research methodology used for review of the previous literature. Section 3 presents the results of the study acquired through bibliometric analysis and content analysis from the selected articles. Section 4 discusses the results, and Section 5 concludes the study by summarizing the results with some limitations and directions for future research.

2 Material and Methods

A comprehensive literature review is performed in this study using rigorous systematic data collection protocols and diverse data analysis procedures. The methodology consists five-step rigorous procedure for data collection followed by extensive bibliometric and content analyses. The research methodology is described in the following sub-sections in detail.

2.1 Data collection

A systemized review on the changes and impacts in the construction sector due to the COVID-19 pandemic was performed. The study used a five-step framework for data collection and validation of results as shown in Figure 1. The process starts with establishing the research objectives/ questions, followed by clearly defined conceptual boundaries. In the next step, well stated predefined inclusion and exclusion criteria was applied for scanning all the grey literature such as company reports, conference papers, and white papers. In the final step, the results were validated by a cross comparison among the authors. It is important to mention that the list of research objectives/questions, conceptual boundaries of the study,

inclusion and exclusion criteria, and validation of the search results have been presented with more detail in Figure 1.

As shown in the figure, the conceptual boundary of the study has been drawn as COVID-19 and construction sector. Further, the dataset used in this study was limited to peer reviewed articles published in the Web of Science or Scopus indexed journals. Using various search terms (as the list is given in figure 1), 120 documents were downloaded from the two databases (Scopus and Web of Science). Applying the predefined exclusion criteria such as removing of grey literature, non-English language articles, duplicate, and non-related articles to the subject of interest, 40 documents were removed. The removed documents were included reports from different organizations, books, poster, conference papers, and articles in languages other than English. To identify the relevant articles and validate the results, two authors reviewed the abstracts, introductions, and conclusion sections of all the remaining documents independently. The results of both authors were compared with one another. Major differences of opinions were observed in only four articles, which were sent to a third researcher for independent review and a final decision. Thus, the inter-rater reliability was 0.95, which indicated higher strength of the agreement between the reviewers. Through this rigorous process, a sample of 53 articles was finalized for analysis in this study. The procedure applied in this study for data collection is in line with previous studies such as Ayat et al. (2020) and Gupta et al. (2019).

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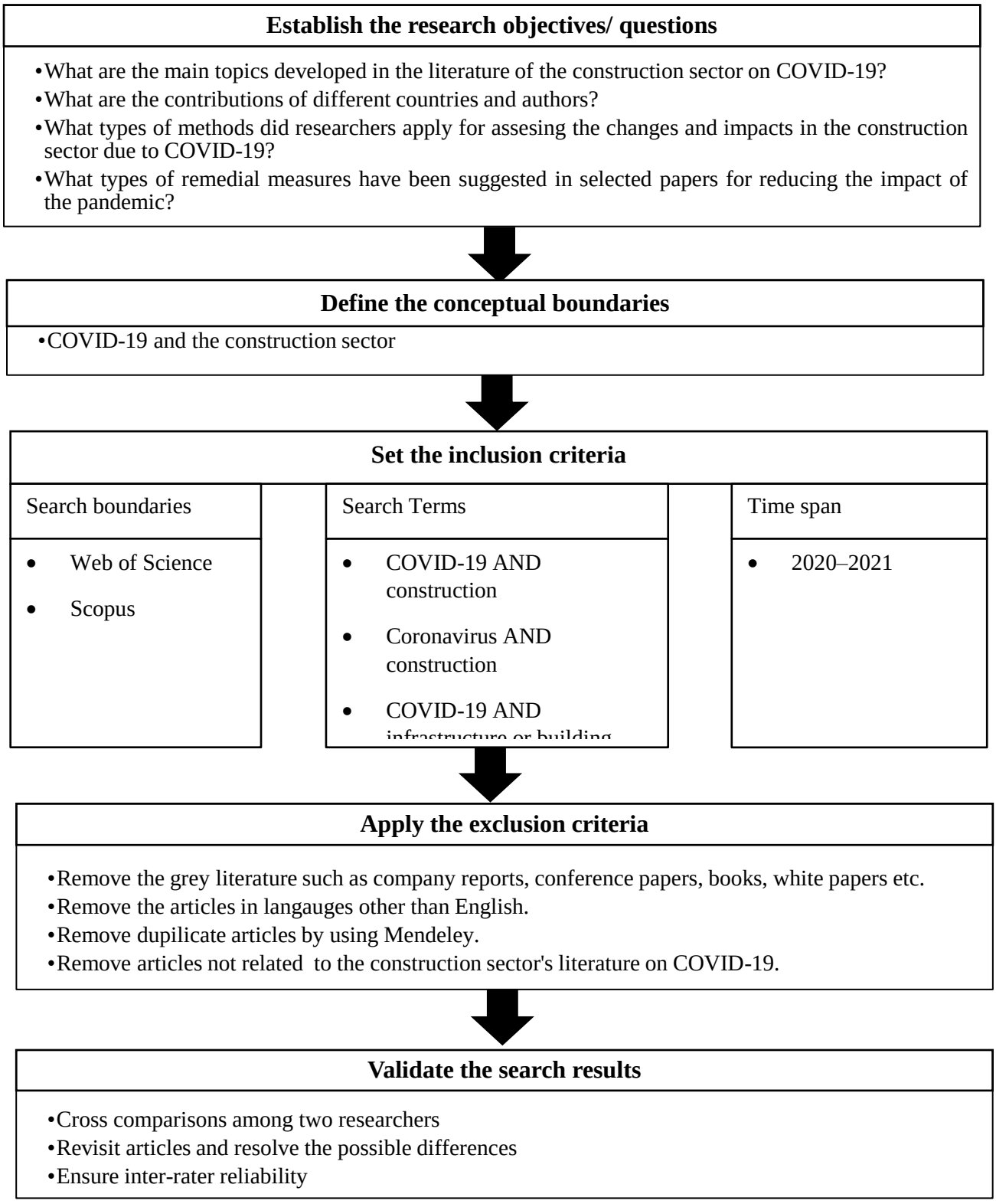

Figure 1: Flow diagram of the SLR process

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2.2 Data Analysis

After the selection of articles, detailed bibliometric and content analyses were performed. The bibliometric analysis and content analysis were further divided into sub-categories to systematically investigate and analyze the contents of the selected articles. The components of these steps are described in the following sub-sections. Figure 2 highlights the methods used for data analysis in this study.

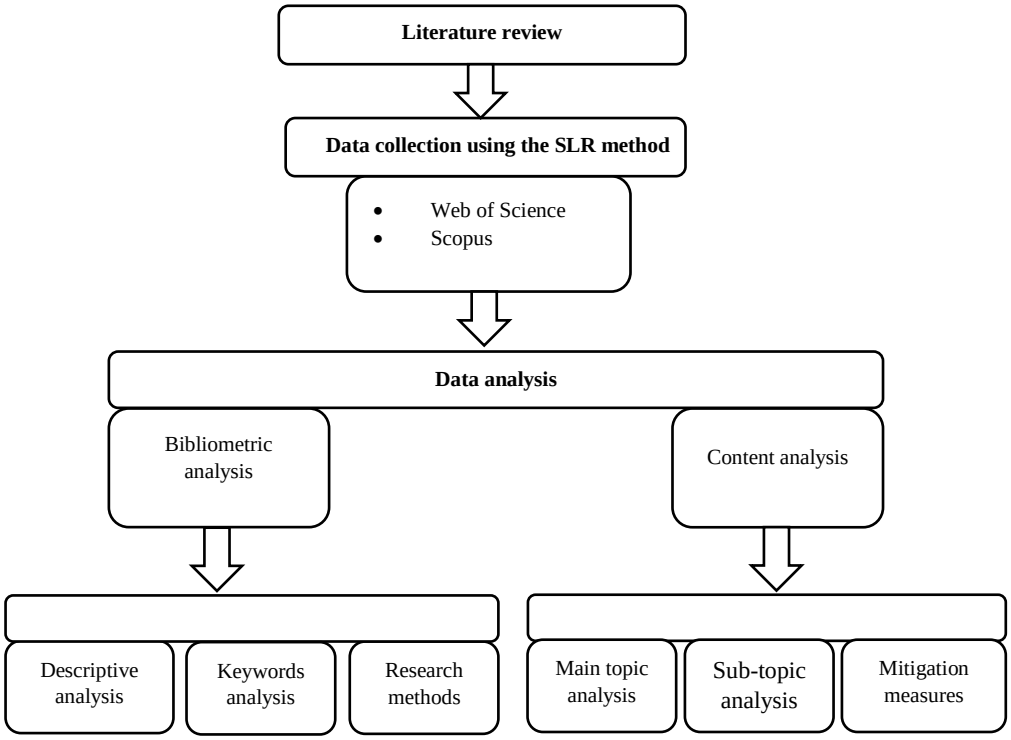

Figure 2: Research design

2.2.1 Bibliometric analysis

Bibliometric analysis is an extensively used method for data extraction through certain databases to analyze and understand the contributions and trends in the subject area of interest (Ng & Chai, 2015). In this study, bibliometric analysis is used for understanding the contribution of different authors and countries, sources of articles, citations, and geographic spread in research activities. The Scopus database was used for extracting the bibliometric information and VOSviewer (version 1.6.16) was used for bibliographic mapping to visualize the information. For the purpose of clarity and to systematically present the extracted information, the bibliometric analysis was divided into three different sub-methods: descriptive analysis, keyword analysis, and research method classification.

2.2.1.1 Descriptive analysis

In this study, descriptive analysis was used to identify the total link strength, the number of citations received by each author and country, influential authors, and the countries with the greatest number of articles published during the time period (January 2020 to July 2021). Furthermore, it provides information about the types of institutions (academic or non-academic) who participated in research to explore the impact of the COVID-19 pandemic on the construction sector.

2.2.1.2 Keyword analysis:

A keywords co-occurrence network is a commonly used research method for the identification of research topics (Wang & Ngai, 2020). This method explains the structure and relationships among keywords (Su & Lee, 2010) to identify and understand frequently used keywords. Keywords co-occurrence analysis was carried out using VOSviewer software similar to a previous study (Piccarozzi et al., 2021). A total of 220 keywords were first identified from the selected articles. Then, the authors carefully reviewed the list of keywords to remove the overlaps and redundancies. Several related keywords with the same basic meaning but differing in word form or spelling in the selected articles were combined into a single keyword. For instance, safety measure and safety measures; building information modelling and building information modeling; worker safety and workforce safety were combined as safety measures, building information modeling, and workforce safety, respectively. After this process, a total of 182 different keywords were finalized for further analysis. A similar method of keyword filtration was used in a previous study by Artto et al. (2009). A list of frequently occurring keywords was identified, and a co-occurrences network was developed using VOSviewer software to visualize the highly weighted keywords.

2.2.1.3 Research methods

Researchers use different types of methodologies, along with various research designs for providing research problem specific solutions (Williams, 2007). Based on the nature of the problem and data, different research methods have to be implemented (Creswell & Creswell, 2017). Orlikowski and Baroudi (1991) divided research methods into two major groups: conceptual and empirical methods. Empirical research is based on experiments, observations, and verifiable evidence whereas conceptual research is related to abstract ideas or concepts that do not involve any experiments or empirical research. This study also follows the same classification of research methods as empirical and conceptual. However, to do in-depth analysis of research methods, the empirical method was further divided into qualitative, quantitative, and mixed methods.

2.2.2 Content analysis

Bibliometric analysis is an important tool to assess academic output, but it does not give detailed information about the contents of the subject of interest (Esen, Bellibas, & Gumus, 2020; Liang & Shi, 2021). Therefore, in order to acquire an in-depth understanding of the topics discussed by researchers in

the selected articles, content analysis was used in this study. Content analysis is a qualitative research technique that is used to interpret meaning from the content of the text data. There are three commonly used content analysis approaches: conventional, directed, or summative (Hsieh & Shannon, 2005). Conventional content analysis is used when the existing theory or literature is limited on the subject. In such cases, researchers avoid pre-determined coding categories (Kondracki, Wellman, & Amundson, 2002). In this study, we used conventional content analysis in which the coding categories were directly taken from the text data because of the unprecedented nature of the problem at hand.

The content analysis in this study has three major parts: main topic analysis, sub-topic analysis, and analysis of the mitigation measures. The main topic analysis was carried out to understand the main subjects of the reviewed articles whereas the sub-topic analysis was performed to obtain detailed information about the various types of impacts of the pandemic on the construction sector. In the third part, an analysis of the mitigation measures was done based on the strategies suggested by the researchers in order to build a comprehensive framework of mitigation measures for the negative impacts of the pandemic on the construction sector.

3 Results

As discussed in the previous section, the results in this study are based on two types of analyses, bibliometric and content.

3.1 Bibliometric analysis

Bibliometric analysis was carried out to extract and analyze the information from the selected articles. For clarity of presentation, the bibliometric results were divided into three sub-categories: descriptive analysis, keywords analysis, and research methods as detailed below.

3.1.1 Descriptive analysis

In this study, 53 peer reviewed articles published during the current pandemic were finalized for analysis. Most of the selected articles were published in 2021 (39 articles) while 14 were published in 2020. The analysis showed that 180 authors from 27 countries and 99 institutions participated in publishing research related to the impact of COVID-19 on the construction sector in 46 different journals (Web of Science or Scopus indexed journals). The prevalence of the institutions was academic (84). However, there were also 15 authors from non-academic institutions who participated in related research activities. The data in Table 1 show that only two authors published four articles, and 11 authors published two articles as co-authors.

The data in Table 2 show that authors from 27 countries participated in studies related to COVID-19 and the construction sector. Some of the studies were carried out in collaboration with authors from different countries. Therefore, it is important to explain that in the case of a study carried out in collaboration

Table 1: Number of articles by the most productive authors

S. No.	Author	Number of Articles	Institution	Country	Number of Citations	Total Link Strength
1	Christopher Amoah	4	University of the Free State	South Africa	9	4
2	Simpeh Fredrick	4	University of the Free State	South Africa	9	4
3	Felipe Araya	2	Universidad tecnica federico santa maria	Chile	9	0
4	Shulei Gao	2	China University of Mining and Technology	China	0	2
5	Lingun Mi	2	China University of Mining and Technology	China	0	2
6	Guodong Ni	2	China University of Mining and Technology	China	0	2
7	Yaning Qiao	2	China University of Mining and Technology	China	0	2
8	Ke Shang	2	China University of Mining and Technology	China	0	2
9	Wenshun Wang	2	China University of Mining and Technology	China	0	2
10	Jinwen Xing	2	China University of Mining and Technology	China	0	2
11	Helen Lingard	2	RMIT University	Australia	0	2
12	Ankan Biswas1	2	JIS College of Engineering,	India	1	2
13	Yuting Fu	2	China University of Mining and Technology	China	0	2

by authors of two or more countries, it was counted for each country separately. As Table 2 shows, authors from the United States (10 articles) contributed the most articles followed by China (9 articles), and South Africa (7 articles). The citation data show that Chile received more citations per item (4.5 citations) followed by China (3.334 citations), and Saudi Arabia (3.334 citations). Furthermore, the data show that

Asian countries (14 countries, 30 articles) dominated the list, followed by North America (3 countries, 13 articles), Africa (4 countries, 12 articles), Europe (5 countries, 11 articles), and Australia (1 country, 6 articles).

Table 2. Number of articles by country

Rank	Country	Number of Articles	Number of Citations	Total Link Strength
1	United States	10	27	9
2	China	9	30	4
3	South Africa	7	11	8
4	Australia	6	9	6
5	United Kingdom	6	12	4
6	Malaysia	3	5	3
7	Saudi Arabia	3	10	2
8	India	2	1	0
9	United Arab Emirates	2	0	0
10	Chile	2	9	0
11	Ghana	2	1	1
12	Indonesia	2	1	0
13	Ireland	2	3	2
14	Nigeria	2	2	3
15	Singapore	2	0	5
16	Canada	1	1	0
17	Brunei Darussalam	1	0	1
18	Greece	1	0	0
19	Iran	1	0	2
20	Japan	1	0	0
21	Jordan	1	3	0
22	Lebanon	1	0	2
23	Lithuania	1	0	0
24	Morocco	1	0	0
25	Pakistan	1	1	1
26	South Korea	1	0	1
27	Sweden	1	0	4

3.1.2 Keyword analysis

A keyword analysis was conducted with a total of 205 keywords used by authors in the selected articles. The list of the most frequent keywords is given in Table 3. The data show that COVID-19 was the top keyword with 50 occurrences followed by the construction sector with 33 occurrences, safety measures 12 occurrences, construction workers 8 occurrences, and challenges, pandemics, and prefabricated structures with seven occurrences each. The value of the total link strength also indicates that COVID-19, construction sector, safety measures, health and safety, and construction workers were the most strongly connected keywords. Other prominent keywords were risk management, building information modeling, force majeure, and technology adoption. The keyword co-occurrence network as given in Figure 3 represents the topical clusters among the keywords. In the given network, the lines show the connections among the keywords whereas the size of the label and marker of the keyword show their weight. The network shows that COVID-19 and the construction sector are the central keywords connected to the highest number of keywords. The keyword analysis highlights the main topics related to the impact of COVID-19 on the construction sector including challenges to the construction sector, health and safety measures, construction workers and their safety, risk management and mitigation strategies, building information modeling, and technology adoption.

272 Table 3: Keywords occurrences and total link strength

S. No.	Keyword	Occurrences	Total link strength
1	COVID-19	50	183
2	Construction sector	33	115
3	Safety measures	12	40
4	Health and safety	9	34
5	Construction workers	8	31
6	Challenges	7	30
7	Pandemic	7	26
8	Prefabricated structures	7	24
9	Risk management	4	18
10	Building information modeling (BIM)	3	15
11	Coronavirus	3	11
12	Force majeure	3	9
13	Technology adoption	3	20
14	Agent-based modeling	2	5
15	Construction project delay	2	13
16	Distance learning	2	14
17	Economic recession	2	13
18	Emergency situation	2	14
19	Fourth industrial revolution technologies	2	9
20	Impact	2	10
21	Measures	2	10
22	Mitigation strategies	2	16
23	Structural equation modeling	2	13
24	Supply chain	2	10
25	Workforce safety	2	13

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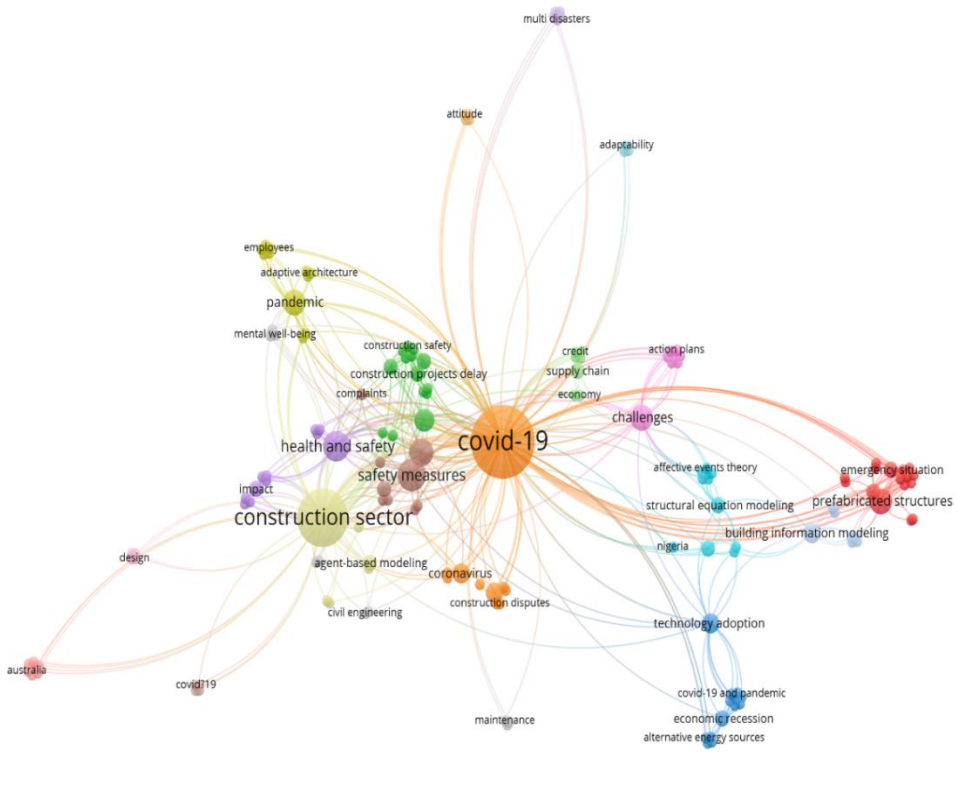

3.1.3

Research Method classification

This section presents the methodological characteristics of the selected articles. The methodologies used by researchers to investigate the impact of COVID-19 on the construction sector were analyzed and distinguished using empirical and conceptual methods. The results show that the majority of researchers carried out empirical studies (45 articles) whereas some researchers also performed conceptual studies (8 articles). A detailed classification of the research methodologies and applied techniques is given in Table 4. The empirical methods were classified into three major categories: qualitative (22 articles), quantitative (18 articles), and mixed methods (3 articles). An analysis of the method of data collection showed that 15 articles used interviews for data collection, seven articles applied questionnaire surveys, three articles used a mixed methodology, and 8 articles used quantitative secondary data collected from various databases. In quantitative methods, surveys and secondary data were combined with different statistical methods such as predictive mathematical models, descriptive statistics, and structural equation modeling. Predictive mathematical models included multiple regression (3 articles), agent based modeling (2 articles), a nonlinear autoregressive distributed lag model (1 article), and log linear regression modeling (1 article).

Table 4: Classification of the research methodologies

Primary method	Sub-category	Techniques	Number of papers
Empirical study	**Qualitative method**	Content analysis	6
		Thematic analysis	6
		Case study	5
		Phenomenological analysis	1
		Grounded theory	1
		Simultaneous importance performance analysis (SIPA) matrix	1
		Inductive approach	1
		Other	3
	Quantitative method	Predictive mathematical models	7
		Descriptive studies (quantitative data)	3
		Structural equation modeling	2
		Decision analytical model	1
		Susceptible infected recovered (SIR) model	1
		CYCLONE simulation	1
		Ranking	1
		Other	2
	Mixed methods		3
Conceptual study		Scoping review	1
		Normative juridical research	2
		Narrative review and synthesis of the literature	1
		Other	3

3.2 Content analysis

The results of the content analysis were divided into three parts: main topic analysis, sub-topic analysis, and analysis of mitigation measures. The results of each part were presented separately in the following sub-sections.

3.2.1 Main topic analysis

The current pandemic has severely affected the construction sector (Ogunnusi et al., 2020) and its productivity worldwide (Quartz Africa, 2020). Researchers from across the world have investigated various types of impacts and challenges to the construction sector due to the pandemic through the context of a specific country, region, or without any regional context and reference such as Ghana (Agyekum et al., 2021), Jordon (Bsisu, 2020), Malaysia (Esa et al., 2020), the United States (Alsharef et al., 2021), Gulf corporation council member countries (Umar, 2021), and the general context (Iqbal et al., 2021). Therefore, the scope of each study was identified based on the data or the observational evidence used in the articles to understand the applicability and comprehensiveness of the selected articles. The analysis showed that 37 articles were based on data or observational evidence of a specific country whereas five articles used evidence from the larger regions, namely, North America, Europe, the Gulf regions, and Central Asia. Furthermore, there were also 11 articles that discussed the impact of the current pandemic on the construction sector from a general perspective without any regional references.

The main topic analysis was carried out to present the big picture of the major topics discussed in the selected articles. Based on the initial overview of the sample, the central points and main topics of the studies were identified. In the results, the major topics were grouped into nine categories, as shown in Table 5. The analysis showed that researchers were mainly focused on the challenges and risk to the construction sector due to COVID-19, health and safety issues, uses of prefabricated structures, future changes, adoption of technologies by sector, contractual complications, changes in working styles, and remedial measures.

The prominent challenges to the sector discussed in the selected articles included challenges to building contractors (Sierra, 2021), challenges of COVID-19 safety measure implementation at construction sites (Amoah & Simpeh, 2020), and general challenges in the construction sector owning to the current pandemic (Oey & Lim, 2021). Furthermore, studies carried out to investigate different types of risk due to COVID-19 such as an expected increase in suicidal risk in the construction sector (King & Lamontagne, 2021), legal risk (Januarita & Sumiyati, 2020), and specific risk factors to tunneling related projects due the current pandemic (Wang et al., 2020).

The analysis further showed that health and safety in the construction sector has emerged as a major topic of investigation for researchers during the current pandemic. Workers and professionals at construction sites are at high risk of infection (Zheng et al., 2020). Several studies have been performed to explain the health and safety aspects of the current pandemic in the construction industry (Avice, 2020; Stiles et al., 2021). Furthermore, researchers highlighted the effect of COVID-19 on contractual relations (Yas, 2021), and working in multiple shifts (Araya, 2021).

In additional to the adverse impact of the pandemic, it has also brought changes and strength to the digitalization process in the construction sector. For instance, using prefabricated and modular composite

structures to build medical facilities in a shorter time without compromising COVID-19 protocols (Bhatti & Wahab, 2021; Chen et al., 2021; Gbadamosi et al., 2020), adoption of building information modeling (Wang et al., 2021), smart buildings (Osunsanmi et al., 2020), and the role of Industry 4.0 in the recovery of the construction sector (Ebekozien & Aigbavboa, 2021). Moreover, researchers have discussed the expected changes in architecture design (Alhusban et al., 2021; Bhatti & Wahab, 2021), requirements of house flexibility (Bettaieb & Alsabban, 2020), and other potential impacts on the housing sector (Allen-Coghlan & McQuinn, 2020). Furthermore, researchers have also presented detailed remedial measures to reduce the impact of the pandemic on the construction sector (Biswas & Bardhan, 2021).

Table 5: Categories of the main topics

S.No	**Main Topic**	**Number of papers**	**Scope of the studies**
1	Challenges and risks	10	South Africa, Philippines, Singapore, USA, UK, China, Indonesia, General (3)
2	Impact of COVID on the construction sector	8	Ghana, USA, Jordan, Malaysia, UAE, Gulf Cooperation Council, General (2)
3	Safety practices	7	Nigeria, USA, South Africa (2), Ghana, UK, General
4	Prefabricated structures	5	Saudi Arabia, UK, China (2), General
5	Implications for future construction	5	Saudi Arabia, South Korea, Jordon, Gulf countries, General
6	Technology, building information modeling, and smart buildings	3	Nigeria, South Africa, China
7	Remedial measures	3	USA, South Korea, North America
8	Contractual implications	2	UK, General
9	Remote working and shift work	2	Australia, General
10	Other	8	Australia, Japan, China, Ghana, Central Asia, Europe, General (2)

3.2.2 Sub-topic analysis

To understand the detailed factors discussed in the selected articles, a thorough analysis of sub-topics was carried out. In the sub-topic analysis, the authors reviewed each article from the sample carefully to identify and explain the nature of the impact of COVID-19 on the construction sector. Based on the analysis, all the identified factors were grouped according to their similarities in content in three distinct categories, namely, negative impacts, positive impacts and new opportunities, and Barriers to COVID-19 safety guidelines as given in Table 6. The purpose of this categorization was to make them presentable and easy to understand.

3.2.2.1 Negative impacts

The current pandemic has caused unprecedented healthcare, economic, and social crises to the modern world. It has resulted in multi-faceted impacts and magnified the inefficiencies and weaknesses of the construction sector. The challenges faced to organizations and the workforce in the construction sector due to COVID-19 have brought negative consequences to many projects. This study gathered 19 adverse factors from the selected articles posed by the pandemic to the construction sector, as shown in Table 6. The prominent challenges to the sector include the disruption of the supply chain (Agyekum et al., 2021; Ankan Biswas & Bardhan, 2021; Sami Ur Rehman et al., 2021; Sierra, 2021), price hikes (Alsharef et al., 2021), contractual complexities (Ankan Biswas & Bardhan, 2021; Bsisu, 2020), disputes (Raoufi & Fayek, 2020), delay in payments (Sami Ur Rehman et al., 2021), shortage of suitable manpower, materials, and equipment (Agyekum et al., 2021; Ankan Biswas & Bardhan, 2021), job loss (Bsisu, 2020), psychological and emotional suffering of the workforce (Asis, 2020), low productivity (Oey & Lim, 2021), interruption of planning and scheduling (Esa et al., 2020), project overruns (Sami Ur Rehman et al., 2021; Umar, 2021), and even suspension of projects (Agyekum et al., 2021; Alsharef et al., 2021).

3.2.2.2 Positive impacts and new opportunities

Apart from the several negative impacts of fhe COVID-19 pandemic, it appears to some extent as a blessing in disguise for the construction sector. The current pandemic may help the sector to grow faster, be more productive, and resilient against future crises. The analysis of the selected articles in the sample shows that researchers have discussed various types of positive impacts of the pandemic on the construction sector including comprehensive training of the local workforce to substitute for foreign workers (Bsisu, 2020), strict compliance of safety measures (Gan & Koh, 2021; Simpeh & Amoah, 2021; S. Stiles et al., 2021), suitable accommodations for workers (Esa et al., 2020), recruitment of skilled labour (Alsharef et al., 2021), operational excellence, flexibility in logistics (Iqbal et al., 2021), and establishment of strong internal review systems (Alsharef et al., 2021). Furthermore, it showed new directions of long waiting

digitalization practices in the construction sector (Wang et al., 2021; Chen et al., 2021) and encouraged investment in research and development (Iqbal et al., 2021).

3.2.2.3 Barriers to COVID-19 safety guidelines

The current pandemic is unprecedented in nature and has disturbed every aspect of life including the construction industry. After the development of COVID-19 guidelines for many industries, their implementation was a great challenge. The challenges were even more serious for the construction sector due to the nature of construction activities and use of labour-intensive methods at construction sites (Araya, 2021). Researchers have discussed several challenges and barriers to the implementation of COVID-19 guidelines in the construction sector including difficulty in compliance with social distancing rules (Ebekozien & Aigbavboa, 2021), misinformation about COVID-19 (Simpeh et al., 2021), sharing tools and equipment (Iqbal et al., 2021), high cost of implementation of safety guidelines (Esa et al., 2020; Simpeh et al., 2021), lack of funds to implement the guidelines, and shortage of quality PPE (Simpeh et al., 2021).

Table 6: Impact of COVID-19 on the construction sector

Category of Impact	**Sub-category**	**Sub-topics**	**No.**
Negative impacts	Organizational impacts	Disruption of supply chain	4
		Price hikes of materials and equipment	5
		Delays in payment	4
		Backlog of outstanding salaries	1
		Delays in inspections and securing permits	1
		Shortage of suitable manpower, material, and equipment	8
		Loss of revenue and increase in additional expenses	3
		Uncertainty of survival	1
		Contractual complexities	4
		Expected Increase in disputes, litigation, and claims	2
	Projects	Interruption of planning and scheduling	3
		Delays in the starting date for new projects	2
		Increases in project time and cost	8
		Suspension of projects	4
	Workers	Job loss and worker layoffs	9
		Traveling restrictions	3
		Psychological and emotional sufferings	3
		Decreases in working efficiency	4
		Expected increase in suicide risk in construction workers	1

Positive impacts and new opportunities	Workers	Training of local workforce to substitute for foreign labour	2
		Recruitment of a skilled and flexible workforce	2
		Education of workers about the pandemic	4
		Compliance of workforce to safety measures	2
		Managing suitable accommodation for workers	3
		Availability of PPE at work site	2
	Process	Restructuring the organization	2
		Operational excellence	1
		Flexibility in logistics	1
		Conducting internal reviews to improving existing systems	1
	Digitalization	Investment in R & D	2
		Acceleration of the digitalization process	5
Barriers to COVID-19 safety guidelines	Type of barrier	Lack of understanding of COVID-19	3
		Difficulty in compliance with social distancing rules due to the nature of construction activities	1
		Compulsion of sharing tools and equipment	1
		Usage of public transport by workers	1
		Misinformation about COVID-19 (COVID-19 is for a particular group of people)	1
		Lack of funds to implement COVID-19 regulations	2
		Poor supply of personal protective equipment (PPEs)	1
		Theft of COVID-19 materials	1

3.2.3 Analysis of mitigation measures

This section presents a mitigation framework based on the various mitigation measures discussed in the selected articles. Around 24 articles in the sample suggested different types of mitigation measures to reduce the impact of the current pandemic on the construction industry and to make it more robust for future crises. After a comprehensive review, around 40 different mitigation measures were extracted from the selected articles. These measures were grouped into five categories, namely, implementation of safety guidelines, methodology/process improvement, government interventions, psychological support, and technology adoption, as shown in Table 7. Some of these mitigation measures have already been implemented in construction industries in different parts of the world. However, this comprehensive list is still useful for practitioners to get a complete overview of the mitigation measures.

402 Table 7: Analysis of the mitigation measures

Category	Mitigation measure
Implementations of safety guidelines	Provision of PPEs including face shield, face masks, gloves, sanitizers, disinfectants etc.
	On-site labor accommodations
	Special travel arrangements
	Medical facilities
	Regular testing and effective checks
	Installation of temperature guns and disinfecting tunnels on entrances/ exits (if possible)
	Increased outdoor air through proper ventilation
	Installation of physical barriers such as protective dividing screens
	Effective record keeping systems to trace contacts
	Appointment of a COVID-19 health supervisor
	Incentives for employees who strictly follow safety guidelines
	Employee pay deductions from those who do not adhere to pandemic safety guidelines
	Regular awareness sessions to educate employees about COVID-19
	Flexible sick leave policies
	Risk assessment for work-related exposure
Methodologies/ process improvement	Remote work
	Enhancement of communication and awareness
	Optimization of manpower management (reduce, rotate, balance, localize)
	Optimize working time on site (overtime, flexible shifts, work from home, holiday use)
	Use of locally made or locally available fixtures
	Flexible project management and coordination skills
	Timely relaunch plan for interrupted projects
	Inclusion of additional cost in budgets associated with COVID-19 safety protocols
	Check and review of existing insurance policies
Government Interventions	Establishment of an anti-COVID-19 task force by the government for the construction sector
	Regular inspections of construction sites by the task force to ensure compliance
	Introduction of a COVID-19 safety compliance certificate by the government
	Funds and subsidies from the government for the construction industry to reduce the risk of default
	Retaining programs supported by governments to reduce unemployment
Psychological support	Industry-based suicide prevention programs
	Investment in mental health services
	Regular counselling sessions for workers
	Expansion of modular/ prefabricated construction

Technology adoption	Acceleration of technology (process digitalization, hit-tech monitoring, modern construction tools etc.)
	Adoption of building information modeling (BIM) instead of traditional approaches
	Roadmap for implementation of Industry 4.0 technologies in the construction sector
	Equipping of engineering graduates with flexible leadership skills required for Industry 4.0
	Preparation by industry to accommodate high implementation costs of digitalized technologies
	Interest-free loans by government for the construction sector for enhancing digitalization
	Clear government policies on issues related to Industry 4.0 technologies

4 Discussion

A bibliometric analysis showed the participation of 180 authors from 99 institutions (84 academics, 15 non-academics) located in 27 countries in different parts of the world. The analysis also showed that the selected articles were published in 46 different journals indexed with the Web of Science or Scopus. Furthermore, the analysis of the scope of the studies showed greater diversity including country specific studies, regional specific studies, and general studies without any geographic context or regional reference. The participation of many authors with diverse backgrounds, diverse sources of articles, greater geographic spread, and the general nature of a reasonable numbers of articles in the sample can make the results of this study useful for both practitioners and researchers in different parts of the world.

Analysis of the research methodologies also showed that diverse methods have been used by researchers to investigates different aspects of the COVID-19 impact on the construction sector. The highest number of empirical studies using interviews and surveys for data collection was due to the suitability of these methods for investigating a new topic that is not grounded in the previous literature. This also shows the importance of collecting and analysing the opinions of the practitioners to investigate and find solutions for new problems such as the COVID-19 pandemic. Furthermore, the results show that around 19 different techniques have been applied by researchers to analyze the quantitative and qualitative data in the selected articles. In this regard, the current study will help researchers to understand how to analyze a new topic from various perspectives using different research approaches. The analysis of the research methodology also confirms the lack of a literature review study related to the impact of COVID-19 on the construction sector.

This study follows a hierarchical framework to identify the areas of interest in the selected articles using keywords analysis, main topic analysis, sub-topics analysis, and analysis of mitigations measures. The keyword analysis highlights the main areas of interest for researchers to analyze the impact of the current pandemic on the construction sector. In addition to COVID-19 and the construction sector, the other most frequently occurring keywords were related to health and safety measures, construction workers and

their safety, risk management and mitigation strategies, building information modeling and technology adoption, pandemic and force majeure, agent based and structural equation modeling.

The main topic analysis shows that the selected articles cover diverse subjects related to the impact of the pandemic on the construction sector. The analysis indicates that the major subject of interest for the researchers was challenges posed by the current pandemic to the sector, related risks, and the health and safety situation of the workers and professionals at construction sites. They have also discussed use of innovative methods such as prefabricated and modular composite buildings, adoption of BIM and other advanced technologies, working from home, and working in multiple shifts.

In the sub-topic analysis, around 39 diverse factors were identified from the selected articles. The analysis shows that the current pandemic has had multiple effects on the construction sector. Researchers have focused on the challenges organizations faced during the pandemic. They emphasized the financial issues, shortage of resources, increase of uncertainty, expected disputes, and contractual implications and disputes among the most significant negative impacts of the current pandemic. The results of the content analysis suggest a multi-faceted impact of the pandemic on construction projects as the construction sector is different from other sectors in many aspects. It has a poor reputation in dealing with external unforeseen events such as war or pandemics and as a result has suffered from issues of poor quality and high project overruns (Smith et al., 2014). The unprecedented nature of the current COVID-19 pandemic has brought higher uncertainty and has slowed down activities in the construction sector (Alsharef et al., 2021; Araya, 2021; ENR, 2020) and significantly affected the supply of construction materials (Jallow et al., 2020). Furthermore, the complexity and ambiguity in forecasting cash flow is another major concern in construction projects (Zayed & Liu, 2014). The payment mechanism in construction projects is lengthy and complex (PWC, 2019), which is prone to risk of price escalation and liquidity issues. The disruption due to the COVID-19 pandemic is further exacerbated by the risk of insolvencies and delays in payments (Alsharef, et al., 2021). Moreover, the construction sector is considered as one of the most adversarial and dispute prone sectors (Steen, 2002) because of the involvement of a large number of stakeholders, numerous complicated tasks, and long project duration (Bunni, 2000). The current pandemic has worsened the situation of contractual disputes in the construction sector. Workers were hit hard during the pandemic as the construction sector is based on labor intensive methods making workers more vulnerable to infection at construction sites. They were also the first to suffer financially from disruption of the construction sector.

Apart from the negative impact, the current pandemic has also brought some improvement and changes to the construction sector. The pandemic has also shown new directions such as the need for rapid digitalization, higher investment in research and development activities, continuous training of workers, and strict compliance to safety guidelines. This study emphasizes that the construction sector should address

these challenges posed by the pandemic by using innovative methods and should take all the necessary steps of improving digitalization in the sector.

The summary of the mitigation measures suggests a five-dimension framework for the construction sector to be more resilient to crises. Firstly, the industry should continue working following COVID-19 guidelines. Secondly, the construction sector and governments should work in closer collaboration to address the current challenges and provide long-term solutions. Thirdly, this study presents diverse measures related to process and method improvements such as optimising available local resources, strengthen internal review systems, applying flexible project management processes, and inclusion of additional cost to effectively respond to the pandemic. Fourthly, organizations should start psychological support programs for the workforce to reduce their fears, worries, and risk of suicide. Fifthly, there should be serious efforts from organisations and government for application of advanced technology to the construction sector. In short, the construction sector needs government support as well as drastic improvements in process and methods, and strict compliance of safety protocols for getting out of the current pandemic completely or adjusting to the new normal. The study also suggests that the construction sector needs to rethink the traditional methods and work with new terms and methods to be more resilient to crises such as the current COVID-19 pandemic.

This study has identified the research methodologies used by researchers for investigating the current pandemic, the major areas of concern, the opportunities COVID-19 provided to the sector for improvement, and detailed mitigation measures for the construction sector to be more resilient to the current pandemic as well as future crises. Therefore, we hope this study will be helpful for practitioners in making effective strategies and informed decisions related to the pandemic. Furthermore, it may be helpful for researchers to identify research gaps and investigate new aspects of the current pandemic on the construction sector.

4.1 Significance of the study

The study was carried out to understand and analyze the international context and implications of COVID-19 on the construction sector. The study has several significance as given below:

- The study summarized the research findings regarding the impact of COVID-19 on the construction sector and grouped them in certain categories including negative impacts, positive impacts, new opportunities for improvement of construction sector, and safety barriers. This systematic presentation of the impacts gives a better understanding of the current situation and highlights the new opportunities and directions for the construction sector.

- The study also put forwarded a comprehensive five-dimension mitigation framework for guiding the stakeholders to reduce the effect of current pandemic and make the sectors more resilient for future crises.
- Furthermore, the study provides a good understanding of the new literature and knowledge development in the construction sector related to responses to pandemics. The study is helpful for researchers to identify and fill the gap in the available literature and look for new aspects of the impact of COVID-19 on the construction sector.

5 Conclusion

This study offered a systemized review to explore the changes and impacts of the COVID-19 pandemic on the construction sector. The analysis showed that the subject has attracted many authors from across the world to investigate the changes in the construction sector owning to COVID-19 using diverse research methodologies and techniques. The analysis shows that the focus of research has been on investigating the challenges and risks due to the pandemic and using innovative methods and tools to deal with these new scenarios for the construction sector. The analysis also shows that apart from the negative impacts, the pandemic has provided some opportunities and new directions for improvement of the sector. This study also presents a five-dimension mitigation framework including implementation of safety guidelines, process and method improvements, psychological support programs, government intervention, and application of technology.

The study has both theoretical and practical implications. It has organized the impacts, challenges, and mitigation measures in a systematic way that provides a clear vision of the development of new literature and knowledge in the construction sector related to the COVID-19 pandemic. From a practical point of view, the findings of this study can guide practitioners to understand the effects of the pandemic on the construction sector and help them in responding efficiently. Though the study has made various contributions as discussed, there are a few limitations. Some articles (11) discussed the subject of interest from a general perspective without any regional reference. However, the majority of the articles in the sample were based on data and evidence from various countries and regions. The primary limitation is that some of the findings presented in this study can be country, region, or organization specific. The study also does not provide any comparison among the countries or regions. In the future, authors may compare the level of the impact of COVID-19 in the construction sector in different countries and regions to better understand the impact from regional perspectives.

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