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Impacts and Response Strategies of the COVID-19 Pandemic on the Construction Industry Using Structural Equation Modeling

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Abstract: The COVID-19 pandemic is one of the most serious global health crises. It has had a massive impact on the global workforce and workplaces, causing enormous changes in the working environment and raising concerns among organizations. Due to the pandemic, the construction industry has faced more challenges in delivering projects on time and within budget. This study aims to determine the relationship between the impacts and response strategies of COVID-19 in Sri Lankan construction projects. A systematic literature review and semi-structured interviews with industry professionals identified twelve COVID-19 impacts and twenty-two response strategies needed to mitigate the impacts. A structured questionnaire survey was then conducted with Sri Lankan construction professionals. The gathered data were analyzed using the Kruskal–Wallis test, exploratory factor analysis (EFA), and partial least-squares structural equation modeling (PLS-SEM). A model and six hypotheses were developed to explain the impact and strategy. The results revealed that it is necessary to focus on the impacts related to the project, develop the necessary strategies from a financial point of view, and supply the necessary materials and equipment. During COVID-19, organizational management and information exchange should be enhanced, along with a project's workforce and its provision. The study findings could aid industry professionals and policymakers in comprehending the pandemic and developing strategies to mitigate the effects of COVID-19 on Sri Lankan construction projects.

Keywords: COVID-19 impacts; response strategies; construction industry; structural equation modeling; exploratory factor analysis

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1. Introduction

The construction industry, like many others, has been adversely affected by the COVID-19 pandemic in many ways. As a result of the COVID-19 epidemic and a shortage of personal protective equipment (PPE) for construction workers, employment possibilities have declined since its inception [1]. The pandemic of COVID-19 has significantly affected the engineering and construction industries. Client talks are anticipated to postpone or cancel construction projects. The global and regional supply chains are under stress, and employee health and safety are issues. Most crucially, because many construction and development organizations lack substantial cash reserves, the lockdowns may compel them to restructure debt, seek new financing sources, or face insolvency [2].

Moreover, in the construction business, all employees and technical engineers are needed to work nearly solely on-site to accomplish duties or check that work is performed appropriately. This is necessary for two reasons: to guarantee that work is performed properly and to accomplish the jobs themselves. The construction business is essentially unique from other sectors in that all project personnel are often required to be on site. This criterion significantly distinguishes the construction business. Consequently, it is crucial to comprehend how the building sector reacts to this unplanned event [3]. During the pandemic, there was a lack of building supplies, which harmed the construction business. Many countries implemented measures to restrict human movement following the pandemic, which primarily hampered the construction industry because it necessitated on-site work. Specifically, in the construction industry, all work activities must be checked and monitored by each project team member [1].

In order to mitigate the impact of COVID-19 on the construction industry, it is necessary to recognize the new issues encountered by industry players in this complicated situation. The collected data are reviewed to produce solutions for reducing the consequences of the crisis. Last but not least, the most effective answer to each issue is determined by analyzing the most important solutions. However, the construction company has unique class types and project types. Small and medium-sized companies (SME) contractors may have a different perspective than larger contractors on the issues provided by COVID-19, and alternate methods are necessary to meet these challenges. Similarly, problems on construction projects and infrastructure projects may differ. To determine the most effective methods for resolving COVID-19-related concerns in the construction industry, it is crucial to define these concerns comprehensively [4].

Despite this, a significant percentage of construction workers tested positive for COVID-19. In fact, according to a recent study conducted in Los Angeles, construction workers reported the highest number of positive incidents compared to workers in other industries, such as transportation, healthcare, and manufacturing [5]. Similarly, other studies have shown that construction workers are almost five times more likely to be hospitalized owing to COVID-19 than workers in other industries [6]. Several other state authorities have also highlighted the possibility of COVID-19 infections, particularly among construction workers [7].

This study intends to close the knowledge gap about the impacts of the COVID pandemic on the Sri Lankan construction sector, hence shedding light on the essential countermeasures. It intends to evaluate the link between COVID-19's affects and reaction measures in building projects in Sri Lanka. This study aims to discover (1) the underlying COVID-19 effects on Sri Lanka's construction projects, (2) the underlying COVID-19 reaction techniques for Sri Lanka's construction sector, and (3) the relationships between these underlying impacts and responses. Identifying and classifying reaction techniques and building a framework based on empirical evidence contribute to the growing body of knowledge on COVID-19 crisis management. Lastly, this study supports the learning and sharing of practitioners in order to create endurance, long-term viability, sustainability, and resilience against future natural catastrophes.

2. Research Background

The construction industry, like many other industries, has been impacted in various ways. There have been fewer job opportunities since the pandemic began, which is partly due to work interruptions caused by restrictions imposed to stem the virus's spread and a lack of PPE caused by increased demand among construction workers. Many projects have been halted or postponed due to quarantine-related supply chain disruptions and staff shortages [5,6]. According to a survey conducted by the Associated General Contractors of America (AGC), 28% of its members agreed that COVID-19 caused them to suspend or postpone projects in the United States [7]. There is always a labor shortage in the construction industry, and the pandemic has exacerbated it [8]. Because COVID-19 spreads primarily through human contact, interactions between construction workers have played a significant role in controlling infectious diseases [1]. Physical distance laws intended to reduce viral transmission have influenced the number of people authorized to work in a specific location, how employees perform their duties, and how project managers anticipate the working environment [9]. Employee health and safety are concerns in both global and local supply chains. Most importantly, if construction organizations do not have significant cash reserves, the impact of the lockdowns may force them to restructure debt, seek new sources of finance, or face bankruptcy.

Acceding to [4], the economic damage induced by the pandemic scenario in Sri Lanka was alert to the large decline of the local currency. Several industries were significantly damaged throughout Sri Lanka as it remains widespread globally. Therefore, prior work outlined how industries were impacted, and response strategies were implemented [10]. According to reports, the overall value of the construction industry in Sri Lanka is INR 397.77 billion. In total, 188,877 individuals are active in the construction industry in Sri Lanka, and 680,000 people are directly and indirectly reliant on the industry. Most construction workers receive their wages daily or twice a month. However, there is no information on their salary or whether they have been paid. Looking at the crisis, the central bank of Sri Lanka has offered a range of facilities to small and medium enterprises (SMEs), such as working capital loan programs and investment-purpose credit schemes.

Every contract must be thoroughly reviewed to understand delays, revisions, and notices. Most contracts provide some relief for "force majeure" events [11]. For example, [12] investigated the impact of COVID-19 on the construction industry. COVID-19 negatively affects on-site work operations, bill of quantities, project completion, and contract law, resulting in force majeure situations in Nigeria's construction industry. Contractors and employers believe that the current COVID-19 pandemic is a significant challenge in the construction industry [13]. As a result, the parties should file a claim for force majeure relief as soon as possible. While the industry debates whether a COVID-19-related impact is a force majeure event or a contractual modification, contractors must immediately comply with contractual notification obligations [14].

Most ad hoc adjustments and force majeure rules require contractors to notify upstream within a few days of the event. Delays frequently result in the forfeiture of extra time or expenditures [15]. Contractors must issue alerts as soon as possible, even if the full extent of the impact is unknown. Early warnings are only the beginning. Furthermore, contractors must look downstream for written guarantees that supplies and equipment will be delivered on time [16]. Contractors are forced to investigate alternatives due to a lack of proper guarantees. Prior works have studied COVID-19′s impact on the construction industry. Ref. [17] concentrated on Kuwaiti construction projects and observed delays due to the COVID-19 pandemic. Ref. [18] sought to determine the industry's overall impact. However, construction projects are still severely delayed. In other words, prior works did not investigate the impact of COVID-19 on the construction industry in depth.

Concerning the impacts of COVID-19 on construction engineers and managers, existing literature has primarily focused on identifying the challenges that construction engineers and managers face during a pandemic, such as safety risks and the resulting need to implement safety protocols [19,20], managing construction delays and resource shortages [20], and implementing technologies that enable remote work [9,21]. Ref. [9] emphasized the critical role of project managers in promoting efforts and putting solutions in place to prevent the spread of COVID-19 among construction workers. It has been suggested that incorporating COVID-19 safety procedures into pre-existing safety processes may improve project success. COVID-19 has already impacted construction projects, resulting in supply chain concerns, a halt or delay in planning and inspection timelines, and additional workforce-related measures [22].

The construction industry suffered greatly from the pandemic, with extraordinary and unprecedented difficulties in managing and separating personnel, disrupted supply chains, and operating constraints [23]. Furthermore, contractors work in a field that has been profoundly impacted by the pandemic's public health and economic consequences [24]. The pandemic caused concern and significant changes in the construction and housing markets, specifically in the construction, financing, and settlement procedures. As a result, the construction industry's ability to resume normal operations is in doubt. Organizations in the construction industry must identify and plan for the post-crisis construction market and create a clear relationship model between impact and pandemic response strategies [10].

To explore the impact of COVID-19 on the construction industry in terms of the difficulties faced by the contractors, the researchers of this study extracted and analyzed information from various sources using the Web of Science database. The information sources comprise 378 textual and graphic materials published between March 2020 and July 2022, according to the Web of Science database. Figure 1 demonstrates that the vast majority of important information on the subject has been published in online articles, specialist e-journals, early access, proceedings papers, editorial materials, meeting abstracts, review articles, and government regulatory papers. This is due to the topic's originality.

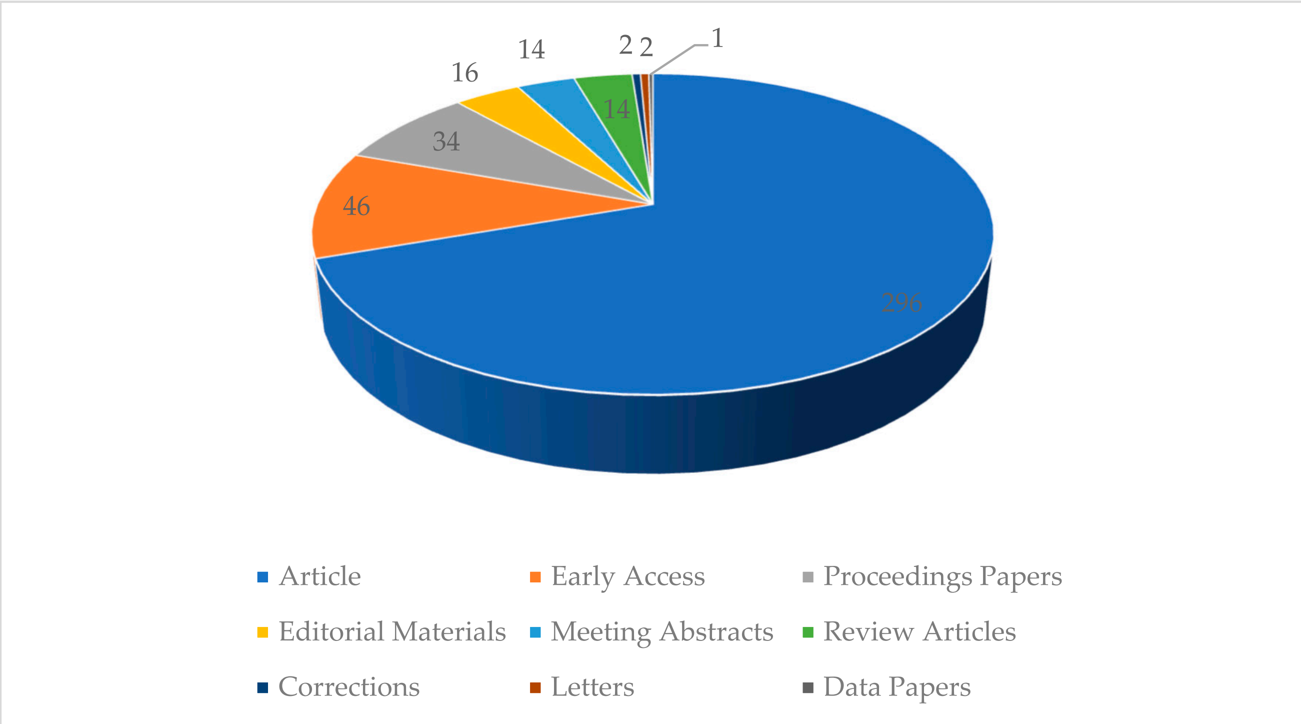

Figure 1. The number of documents covering each type of evidence source based on the WOS database.

A study of the titles and abstracts of the evidence sources was conducted to determine the most often cited and significant categories. This analysis revealed that the difficulties contractors face due to COVID-19 are diverse and can be categorized into the following major themes: civil engineering, industrial engineering, environmental sciences, construction building technology, management, public environmental, occupational health, and green sustainable science technology. Figure 2 illustrates the scattered attention on several areas and the overall interest in each group. Different writers are interested in various facets of COVID-19′s influence on contractors. According to the majority of writers, two factors are of primary concern to contractors: the health and safety of their personnel and the economic impact of this problem on their organizations. In government regulations, health and safety requirements have been explicitly specified. However, the economic impact is not yet obvious. While it is also significant, the first reports are only now being out. There are more texts on the procurement issue because it is open to interpretation, and more writers have written about it. According to the level of attention expressed, the remaining difficulties are less significant than the last. Figure 2 displays the number of accessible papers by category.

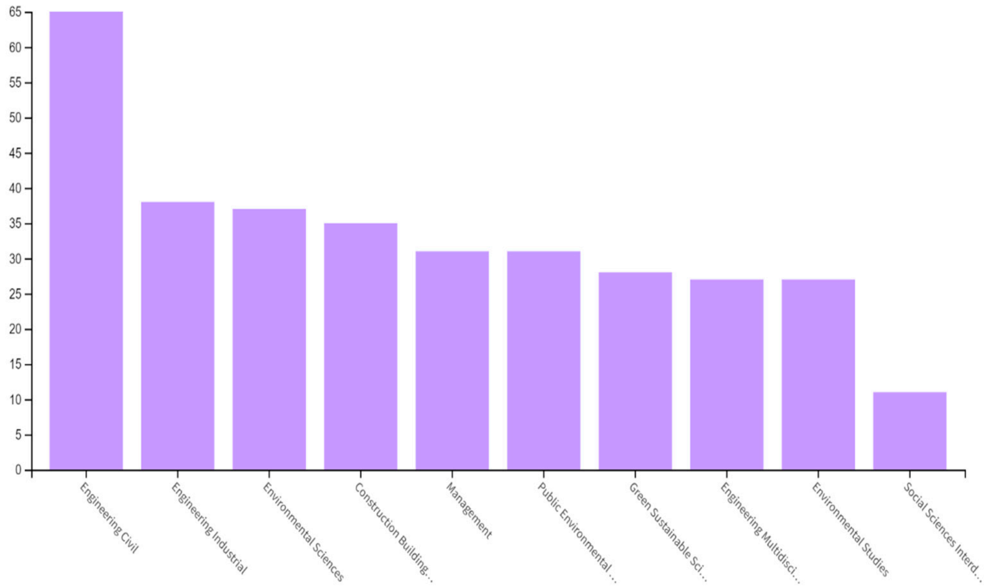

Figure 2. Number of documents per category based on WOS database.

Authorities are developing steps to combat the impacts of the epidemic. For example, policymakers in Sri Lanka [9] and Australia [10] have established response measures to limit the pandemic's consequences. Organizational response strategies include following standard operating procedures, establishing successful relationships with suppliers, and working in shifts [15]. In addition, ref. [13] recommended a number of reaction strategies, such as creating teams to assess the pandemic and provide solutions and using existing government aid programs. The study in ref. [25] evaluated pertinent material and provided reaction strategies for the future of the construction sector post-COVID-19. Portfolio diversification, collaborative contracting methods, industrialized construction, circular economy, remote working, integrated design management utilizing building information modeling (BIM), manning and skills training, changeable building design, augmented reality, automation, three-dimensional printing, and lean construction are among the eleven strategies that construction organizations can use to develop pandemic resilience.

The following six hypotheses were developed to examine the relationships between the impacts and response strategies:

Hypothesis H1: *Project-related impacts require materials, machines, money, and manpower aids for existing projects.*

Hypothesis H2: *Project-related impacts require information and organizational-level aids.*

Hypothesis H3: *Project-related impacts require additional projects and manpower.*

Hypothesis H4: *Material-related impacts require materials, machines, money, and manpower aids for existing projects.*

Hypothesis H5: *Material-related impacts require information and organizational-level aids.*

Hypothesis H6: *Material-related impacts require additional projects and manpower.*

This study is a case study of the impact of COVID-19 on construction projects in Sri Lanka. Prior works have shown that no clear model links the COVID-19 impacts and response strategies in the construction industry. Therefore, the study attempts to comprehend the situation and recommend appropriate strategies to mitigate losses caused by project costs, and schedule overruns caused by the pandemic.

3. Materials and Methods

3.1. Survey Development

One of the methods used to systematically obtain random data is by using a questionnaire survey. Questionnaire surveys have been frequently used to gather views from experts in the construction management domain. Therefore, this study developed a questionnaire survey and used it for data collection. Figure 3 presents the framework of this study. First, a systematic literature review was conducted to identify the impacts of COVID-19 and response strategies. Semi-structured interviews were conducted to identify impacts and response strategies that were not reported in the literature. From the literature review and interviews, a questionnaire was developed, pre-tested, and distributed to the target respondents. After collecting the data, several data analysis techniques were used to analyze the data. Exploratory factor analysis (EFA) was used to identify any statistical relationships between the impacts and the responses by dimension reduction and item classification. Then, partial least-squares structural equation modeling (PLS–SEM) was used to test the complex causal relationships between the impacts of COVID-19 and the response strategies.

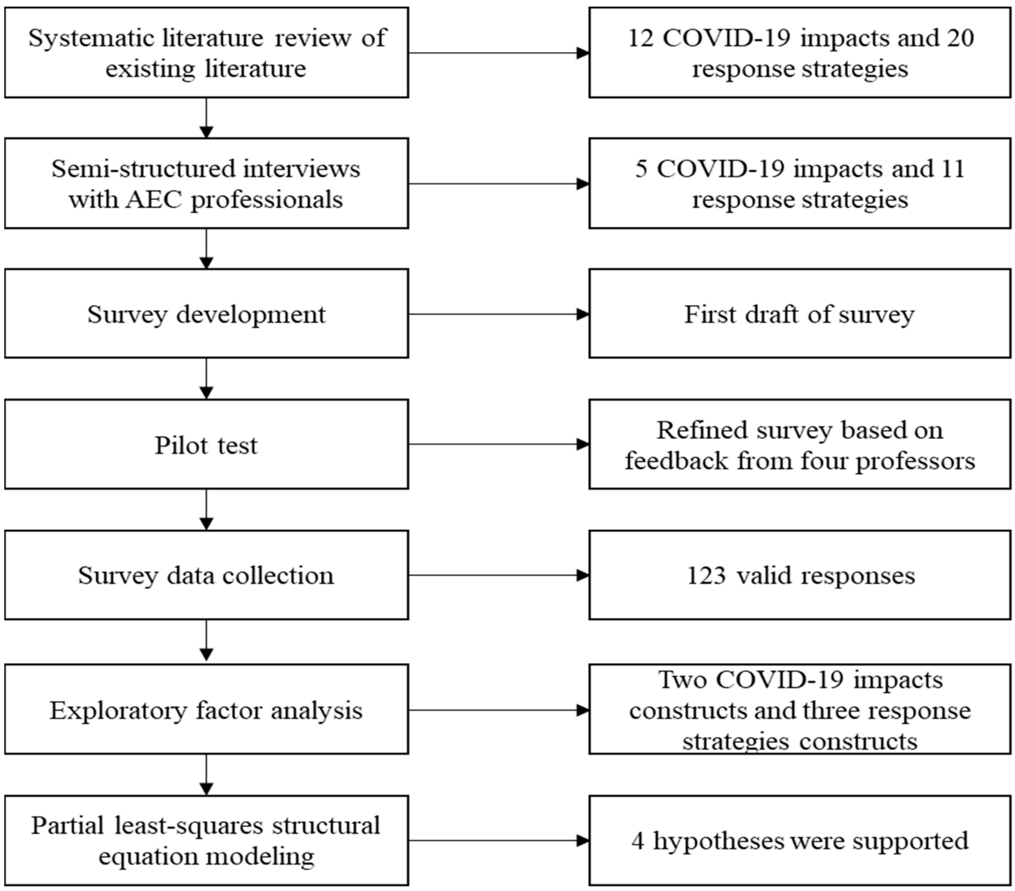

Figure 3. Research framework.

3.1.1. Systematic Literature Review

In order to compile a comprehensive list of possible COVID-19 affects and response methods, this research used a systematic literature review (SLR) approach to systematically examine the current literature. There are two stages to the SLR. The first step was to search the SCOPUS database for articles on construction management by using the terms 'COVID' and 'construction industry' OR 'construction industries' OR 'construction management' OR 'project management' OR 'construction engineering' OR 'construction project' OR 'construction projects. The terms "COVID" and "effect" or "reaction" were used in the second phase. This search restricted its results to articles on "business, management, and accounting" and "economics, econometrics, and finance," respectively. As can be seen in Figures 1 and 2, a total of 519 items were located after the search. Articles that did not directly relate to the research subject were then excluded by reading their titles, abstracts, and full contents. In particular, we excluded from our analysis any publications that did not address the effects of COVID-19 on the building sector or any solutions for dealing with the outbreak. In the end, 72 pieces were located and analyzed. The steps of a systematic literature review are shown in Figure 4.

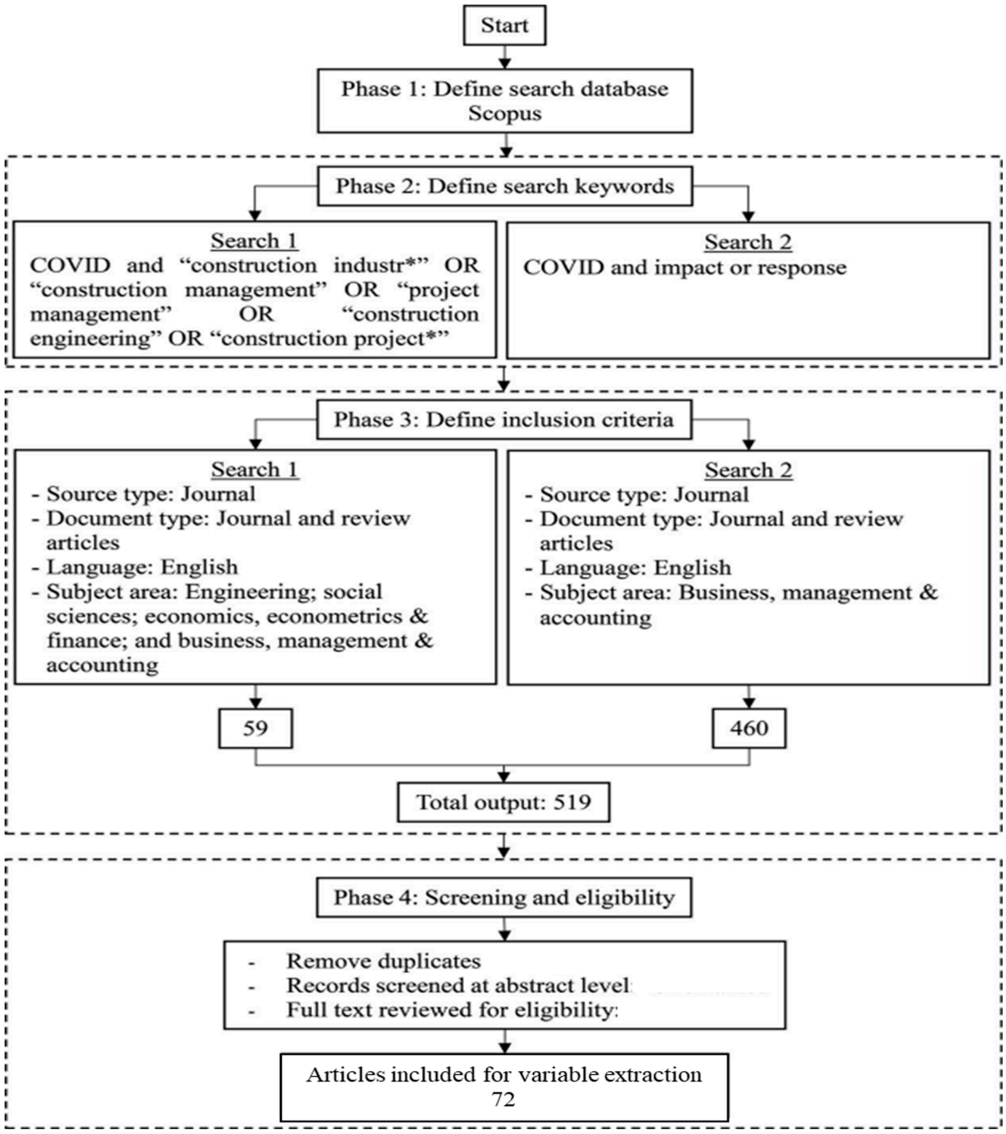

Figure 4. Systematic literature review process [1].

3.1.2. Semi-Structured Interviews

To guarantee the appropriateness and rationale of the survey, a two-step procedure was used during the survey development process. After conducting SLR, forty semi-structured interviews with industry professionals were performed to find additional COVID-19 impacts and response strategies that had not been identified earlier. This step is a common method utilized in previous works in the construction management field to obtain additional variables [25]. Interviewees must hold senior or managerial positions and have five or more years of industry experience to assure the quality of the outcomes. After each interview, a summary was prepared and sent to the respondent for validation. The data from the SLR and the interviews were used to develop the survey. While SLR revealed the COVID-19 impacts and response strategies identified in previous studies, semi-structured interviews with industry practitioners revealed the COVID-19 impacts and response strategies that were not reported in prior studies. Twelve COVID-19 impacts and twenty-two response strategies were produced by combining impacts and response strategies with similar meanings (see Tables A1 and A2 in Appendix A).

3.1.3. Survey Development

The survey was divided into two sections. The study objectives and contact information of the researcher were provided on the front page of the survey. The first section of the survey comprised questions about the participants' backgrounds and organizations. This information is necessary for determining participants' reliability. The second and third sections included the list of COVID-19 impacts and response strategies identified on a five-point Likert scale (1 is not critical and 5 is extremely critical) as shown in Tables A3–A6 in Appendix A. The five-point Likert scale is renowned for its short length [25] and capacity to deliver precise information [26]. Additionally, in the last section of the survey, respondents were provided with an opportunity to describe and evaluate any further impacts and response strategies.

3.1.4. Pilot Test

The pilot test included four professors with a combined 10 years of expertise in construction management. They checked the survey for the proper use of jargon and other technical terms and for clarity. The authors determined that after the fourth participant, there was no further information to be gleaned from the data. If a researcher believes that collecting more data would produce the same findings and validate developing themes and conclusions, they have reached data saturation. Results from the pilot test were used to finish the survey.

3.2. Data Collection

Construction professionals with adequate expertise and knowledge in the construction industry were the subjects of this study. Because there was no sampling frame, nonprobability sampling was used [27]. According to ref. [28], the nonprobability sampling method can be used to obtain a representative sample when a random sampling approach cannot be used to recruit participants from a population. Participants were selected based on their willingness to participate [29]. The entire sample size was determined using the snowball sampling approach. Snowball sampling has been employed in prior construction management research because it allows the collecting and sharing of data and responses via referrals or social media [30]. To determine the first survey participants, industry professionals working in the construction industry were approached. Then, participants were invited to introduce the next persons that might be suitable for the survey according to their professional and academic backgrounds. Two weeks following the first interaction with the participants, two follow-up emails were sent to the target audiences to raise the number of participants. Finally, 123 completed responses were retrieved.

Table 1 presents the respondent's background information. Survey participants were classified according to their years of experience, organizational type (contractor, client, and consultant), and work specialization (building construction (residential), building construction (non-residential), infrastructure construction, and industrial construction). All participants were industry professionals with adequate knowledge of the construction industry, such as engineers, project managers, architects, and quantity surveyors. Most respondents were contractors (42.3%), which was followed by clients (30.9%), consultants (23.6%), and other (3.3%). Approximately 90% of the participants had at least two years of experience working in the construction industry. Participants with less than two years of experience in the construction industry can be deemed as novices. These results reflect great experience in construction, and most of the participants are not novices. Furthermore, 30.9% of the participants worked in infrastructure construction, 22.8% worked in residential building construction, 18.7% worked in non-residential building construction, and 8.1% worked in industrial construction.

Table 1. Respondents profile.

Characteristics	Categories	Frequency	Percentage (%)
Experience in the construction industry	Less than two years	13	10.6
	2 years to 5 years	84	68.3
	6 years to 9 years	22	17.9
	Ten years and above	4	3.3
Type of organization	Client (e.g., government, developers)	38	30.9
	Contractors	52	42.3
	Consultants	29	23.6
	Other	4	3.3
Type of recent project	Building construction (residential)	28	22.8
	Building construction (non-residential)	23	18.7
	Infrastructure construction	38	30.9
	Industrial construction	10	8.1
	Other	24	19.5

4. Analysis and Results

The Statistic Package for the Social Sciences (SPSS) v23 was used for EFA. Other studies [10,25] have also made use of SPSS. In addition, the hypotheses based on structural equation modeling were tested using the partial least squares (PLS) method, and SmartPLS 3 [31] was the program utilized. It is worth noting that SmartPLS 3 has been used in a variety of additional studies [10].

4.1. Exploratory Factor Analysis

EFA is a statistical method for streamlining large amounts of data into a manageable collection of constructs. EFA is used by researchers when they do not know what to expect in terms of patterns or factors among their variables [32]. Principal axis factoring (PAF) was employed to extract EFA because it provides more consistent loadings than competing approaches [33]. There is precedent for this method's use in the literature [34,35].

The appropriateness of the data to conduct EFA was determined using two tests. The first test was the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy. KMO values range between 1 and 0, with values less than 0.50 considered unacceptable. According to [36], KMO values of not less than 0.80 are appropriate for EFA. The second test was Bartlett's test of sphericity. It is used to test the null hypothesis that the correlation matrix is an identity matrix, which indicates that the variables are unrelated among the items. The correlation matrix is not an identity matrix when the significant value is less than 0.05 [36]. The factor loading cut-off value is 0.50 [37].

The ratio of a sample size to the number of variables method was used to calculate the sample size for the EFA method. The minimum ratio value should be 5.00 [38]. For impact data, the sample size to the number of variables ratio was 123/12 = 10.25. For response strategy data, the ratio was 123/22 = 5.59. These results show that the sample size for this study is adequate. The KMO value for the impact data was 0.803, and the KMO value for the response strategy data was 0.917, which is substantially higher than the minimum value of 0.80. Thus, the data were deemed suitable for EFA [36]. The results of Bartlett's test show that the correlation matrix is significant at $p < 0.05$ and hence is not an identity matrix. Thus, EFA can be applied to the data. Only seven impacts were considered in the factor analysis, from which two components were identified. The two components account for roughly 63.191% of the total variance, which is higher than the required 60% for construct validity [39,40]. COVID-19 impacts and response strategies that are highly correlated will share a lot of variances. For the response strategy data, 15 response strategies were finally considered, from which three components were identified. Two components explained approximately 62.339% of the overall variance.

Then, the constructs were subjected to a Cronbach's alpha reliability test to ensure that the impacts and response strategies were properly grouped. In the case of a newly developed scale [41], such as this study, values above the threshold of 0.60 were acceptable [42]. The Cronbach's alpha values for each group ranged from 0.611 to 0.924, which is above the minimum threshold. These results show that each construct possessed good internal consistency. The final EFA results and Cronbach's alpha values are summarized in Tables 2 and 3.

Table 2. Results of exploratory factor analysis on COVID-19 impacts.

Constructs	Code	Factor Loadings	Variance Explained (%)	Cronbach's Alpha
Project-related impact	CI9	0.778	48.531	0.790
	CI10	0.616		
	CI11	0.603		
	CI3	0.557		
	CI12	0.546		
Material-related impact	CI8	0.841	14.660	0.767
	CI6	0.674		

Table 3. Results of exploratory factor analysis on COVID-19 response strategies.

Constructs	Code	Factor Loadings	Variance Explained (%)	Cronbach Alpha
Materials, machines, money, and manpower aid for existing projects	CR18	0.712	47.014	0.924
	CR12	0.706		
	CR11	0.705		
	CR14	0.677		
	CR13	0.673		
	CR17	0.632		
	CR19	0.619		
	CR15	0.608		
	CR22	0.571		
	CR8	0.561		
Information and organizational-level aids	CR6	0.685	8.408	0.803
	CR9	0.639		
	CR5	0.612		
	CR4	0.558		
	CR10	0.508		
Additional projects and manpower	CR21	0.686	6.917	0.611
	CR2	0.575		

4.2. PLS-SEM Analysis

Tests of the hypotheses generated were performed using structural equation modeling (SEM). SEM allows for the direct measurement of observable variables while also allowing for the inference of latent variables from seen data. A structural equation model has both measurement and structural models. In a measurement model, the mapping between the observable and latent variables is shown. On the other hand, a structural model depicts the associations between latent variables. Both covariance-based SEM (CB-SEM) and partial least-squares SEM fall under the umbrella term "structural equation modeling (PLS-SEM). CB-SEM was passed up in favor of PLS-SEM [43] due to PLS-greater SEM's flexibility in dealing with non-normal datasets and smaller sample numbers.

First, the measurement model's validity is evaluated using composite reliability, loadings of each variable on its corresponding construct, and extracted average variance (AVE).

The composite reliability value should be greater than 0.70 to evaluate the internal consistency reliability of the measurement model [44]. In addition, variable loadings should be greater than 0.70 [45–47]. Using the value of the AVE, which should be greater than 0.50, the convergent validity of the measurement model is evaluated [44]. Next, the measurement model's discriminant validity is evaluated. The degree to which one construct differs from others is the definition of discriminant validity [48]. For discriminant validity, the square root of AVE for each construct must be greater than the inter-construct correlation, and the loading of a variable on its construct must be greater than the cross-loadings [46]. After evaluating the measurement model, the significance and relevance of the structural model relationship are then employed to evaluate the structural model's validity.

4.3. Measurement Model Evaluation

4.3.1. Convergent Validity

The construction of reliable measurement models is required for testing the structural model. Therefore, it was important to evaluate the reliability and validity of the measurement models. The AVE values for each construct exceeded the recommended value of 0.50 (Table 4), indicating that the indicators and constructs have a satisfactory level of convergent validity. Furthermore, the composite reliability values of all constructs and variables loadings were greater than the required threshold of 0.70, and Cronbach's alpha values were more than 0.60 [49], which implies that internal consistency reliability is adequate [47]. Measurement model is depicted in Figure 5.

Table 4. Measurement model evaluation.

Constructs	Indicators	Loadings	AVE	CR	CA
Project-related impact	CI10	0.783	0.548	0.858	0.793
	CI11	0.750			
	CI12	0.703			
	CI3	0.666			
	CI9	0.791			
Material-related impact	CI6	0.908	0.814	0.898	0.772
	CI8	0.896			
Materials, machines, money, and manpower aid for existing projects	CR11	0.795	0.595	0.936	0.924
	CR12	0.789			
	CR13	0.750			
	CR14	0.739			
	CR15	0.789			
	CR17	0.797			
	CR18	0.787			
	CR19	0.803			
	CR22	0.717			
	CR8	0.743			
Information and organizational-level aids	CR10	0.770	0.562	0.864	0.806
	CR4	0.750			
	CR5	0.620			
	CR6	0.775			
	CR9	0.819			
Additional projects and manpower	CR2	0.714	0.701	0.822	0.616
	CR21	0.945			

Note: AVE = average variance extracted; CR = composite reliability; CA = Cronbach's alpha.

4.3.2. Discriminant Validity

As seen in the relevant rows and columns of Table 5, the square-rooted AVEs for the constructs were bigger than the correlation coefficients between any two latent constructs, indicating that latent constructs had enough discriminant validity. In addition, crossloading analysis was used to evaluate discriminant validity [50]. All variables loaded higher on the construct they were theoretically meant to assess than on other constructs in the model (Table 6), indicating the discriminant validity of the constructs.

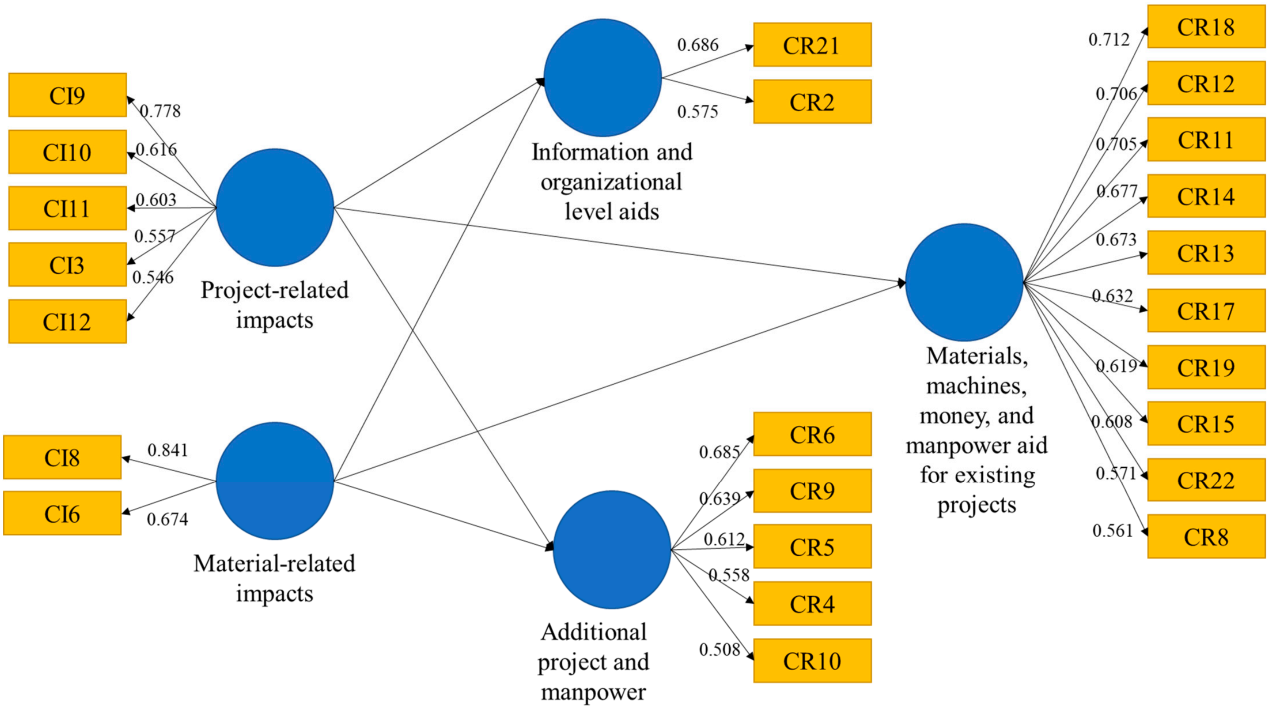

Figure 5. Measurement model.

Table 5. Discriminant validity.

Constructs	Project-Related Impacts	Material-Related Impacts	Materials, Machines, Money, and Manpower Aid for Existing Projects	Information and Organizational-Level Aids	Additional Projects and Manpower
Project-related impacts	0.740	-	-	-	-
Material-related impacts	0.510	0.902	-	-	-
Materials, machines, money, and manpower aid for existing projects	0.546	0.444	0.772	-	-
Information and organizational-level aids	0.458	0.246	0.694	0.750	-
Additional projects and manpower	0.281	0.141	0.489	0.351	0.837

4.3.3. Structural Model Assessment

The bootstrapping approach was used to test the validity of the underlying structural model. We used this method to calculate the probabilities of significant route coefficients and to verify our hypothesis. There are precedents for using the bootstrapping method [10,47]. Five thousand bootstrap samples were the sweet spot [47]. Two-tailed test significance levels of 0.01, 0.05, and 0.10 required t-values of 2.58, 1.96, and 1.65, respectively. Table 7 shows that both of the hypotheses' route coefficients were positive and statistically significant at the 0.01 level. In addition, both of the aforementioned alternative hypotheses (H3 and H4) were supported by the data and showed statistical significance ($p < 0.05$). However, the t-value for the path coefficient for Hypotheses 5 and 6 was below 1.65, suggesting that they are not supported.

Table 6. Cross-loadings.

Indicators	Project-Related Impacts	Material-Related Impacts	Materials, Machines, Money, and Manpower Aid for Existing Projects	Information and Organizational-Level Aids	Additional Projects and Manpower
CI10	0.783	0.497	0.504	0.384	0.122
CI11	0.750	0.312	0.432	0.373	0.186
CI12	0.703	0.350	0.382	0.304	0.289
CI3	0.666	0.363	0.340	0.268	0.229
CI9	0.791	0.355	0.341	0.354	0.231
CI6	0.507	0.908	0.392	0.287	0.093
CI8	0.411	0.896	0.410	0.154	0.163
CR11	0.431	0.325	0.795	0.522	0.365
CR12	0.439	0.387	0.789	0.490	0.336
CR13	0.420	0.431	0.750	0.453	0.326
CR14	0.338	0.274	0.739	0.411	0.392
CR15	0.408	0.317	0.789	0.590	0.483
CR17	0.395	0.271	0.797	0.591	0.374
CR18	0.429	0.391	0.787	0.538	0.301
CR19	0.528	0.400	0.803	0.592	0.508
CR22	0.353	0.269	0.717	0.518	0.318
CR8	0.420	0.309	0.743	0.639	0.354
CR10	0.383	0.258	0.560	0.770	0.320
CR4	0.340	0.163	0.512	0.750	0.371
CR5	0.205	0.071	0.340	0.620	0.142
CR6	0.369	0.202	0.468	0.775	0.130
CR9	0.377	0.185	0.668	0.819	0.321
CR2	0.138	0.076	0.278	0.233	0.714
CR21	0.294	0.144	0.495	0.340	0.945

Table 7. Structural model assessment.

Hypothesis	Path	Path Coefficient	*t*-Value	Decision
H1	Project-related impact > Materials, machines, money, and manpower aids for existing projects	0.431	4.821 *	Supported
H2	Project-related impact > Information and organizational-level aids	0.449	4.184 *	Supported
H3	Project-related impact > Additional projects and manpower	0.282	2.310 **	Supported
H4	Material-related impact > Materials, machines, money, and manpower aid for existing projects	0.225	2.516 **	Supported
H5	Material-related impact > Information and organizational-level aids	0.017	0.155	Not Supported
H6	Material-related impact > Additional projects and manpower	−0.004	0.029	Not Supported

Note: * $p < 0.01$; ** $p < 0.05$.

5. Discussions

The importance of this study lies in examining the relationship between the impact of the COVID-19 pandemic on the construction industries on the one hand and response strategies to face the risks of these impacts on the other. Construction projects worldwide, including the country of the study, Sri Lanka, have been suspended during the period of the pandemic. There were also delays in the delivery of projects according to the schedule specified in the contracts in addition to exceeding the project cost stipulated in the contracts. Costs rose as a result of government measures to limit the spread of the pandemic and apply the principles of social distancing as well as the suspension of commercial flights between countries of the world, which led to the disruption of supply chains and the arrival of materials to project sites in the previously planned period. By studying the literature, the potential impacts of COVID-19 and response strategies to mitigate the impacts were identified. The EFA was conducted using the SPSS program, and the factors with a low load factor were excluded. Then, six hypotheses were developed that explain the relationship between the impacts of COVID-19 and the response strategies in the construction industry. These hypotheses were examined using the PLS-SEM approach.

5.1. Relationship between 'Project-Related Impacts' and 'Materials, Machines, Money, and Manpower Aids for Existing Projects (H1)

Based on ref. [51], construction projects are often afflicted by poor performance, which manifests in delays, cost overruns, low productivity, construction waste, and degraded quality. Table 7 indicates that 'project-related impacts' have a significant path coefficient on 'materials, machines, money, and manpower aids for existing projects", thus supporting Hypothesis 1 (that the effects related to the project are the ones that directly affect the main project elements, i.e., the cost, schedule, and quality, which are all directly related, according to the results of the study, to the materials, machines, money, and manpower of the existing projects, which were directly affected as a result of the outbreak of the COVID-19 pandemic). The reduced number of private projects (CI9) has the highest loading factor in this group, indicating that COVID-19 affected the number of private projects, reflecting the country's economy. Furthermore, the mandate aids for construction loans (CR19) have a significant factor loading among response strategies for materials, machines, money, and manpower aids for existing projects. The correlation between the efficient delivery of construction projects and economic growth in the Sri Lankan construction industry is complicated by managing resources, people, machinery, money, materials, and techniques. Certain projects are handled successfully and efficiently, whereas others are managed ineffectively or inefficiently [52]. The importance of this hypothesis appears in the previous results. It is consistent with prior works on developing responses to overcome the risks of supplying materials and equipment and financial obstacles for construction projects [3,4,10].

5.2. Relationship between 'Project-Related Impacts' and 'Information and Organizational-Level Aids (H2)

According to ref. [53], the impacts of a construction project's surroundings and technical sophistication are examined in terms of how these elements affect project organizations. The environment is evaluated in many ways for its complexity, dynamism, and antagonism. The certainty (or degree to which a technology is well known) of the information employed in a project, its complexity, and the degree of interaction between sub-activities within the project are all considered. Table 7 indicates that 'project-related impacts' have the highest path coefficient on 'information and organizational-level aids", thus supporting Hypothesis 2 (that project-related impacts require information and organizational-level aid). The shortage of materials (CI8) has the highest loading factor in this group, which indicates that COVID-19 affected the supply of the material. According to ref. [54], significant technological and communication advancements facilitated the development of organizations in an environment defined by knowledge-based economies and intensive technology. Knowledge has developed into a critical resource for organizations seeking a competitive edge. Information and organizational-level aids are significant factors to respond to and mitigate the impact of COVID-19 on the construction industry because the basis for the success of construction projects depends on the availability of appropriate and accurate information at the time of need and the organizational capacity of the administration, while facing risks is vital to overcome them with the least possible losses, which applies to the case of the spread of the COVID-19 pandemic.

5.3. Relationship between Project-Related Impacts and Additional Projects and Manpower (H3)

The primary obstacles confronting construction workers during the COVID-19 pandemic include organizational, economic, psychological, individual, and moderating variables. Protecting the workforce, ensuring project performance, and ensuring project continuity are three critical actions that assist construction employees in overcoming health and safety difficulties and ensuring project continuity [55]. Table 7 indicates that 'project-related impacts' have a significant path coefficient on 'additional projects and manpower", thus supporting Hypothesis 3 (that project-related impacts require additional projects and manpower). The provision of infrastructure investment budgets to local governments (CR21) has the highest loading factor in this group, which indicates that contractors require additional projects and manpower during the COVID-19 pandemic.

5.4. Relationship between Material-Related Impacts and Materials, Machines, Money, and Manpower Aids for Existing Projects (H4)

Contractors and sureties face familiar challenges, such as shortages of materials and inefficiencies in labor, but on a scale and for a duration that has never been seen before. In addition, they are facing new challenges in the form of stay-at-home orders and government shutdowns of construction projects considered "non-essential". This study outlines many challenges the construction industry needs to solve as it navigates the likely contractor failures and higher bond claims resulting from COVID-19′s impact on the Sri Lanka construction industry. Table 7 indicates that 'material-related impacts' have a high path coefficient on 'materials, machines, money, and manpower aids for existing projects", thus supporting Hypothesis 4 (material-related impacts require materials, machines, money, and manpower aids for existing projects). The disruption in the supply chain (CI6) has the highest loading factor in this group, which indicates that COVID-19 affected project success due to a shortage of material during the pandemic. Engineering, building, and construction materials are critical in our communities and the economy's post-pandemic recovery. COVID-19′s influence causes a ripple effect in supply networks extending across other industries. COVID-19 also causes both supply and demand fluctuations, which are deleterious. On the contrary, COVID-19 has a cascading impact that spreads across the supply chain's multiple industries (buyers, distributors, and suppliers). There has never been a time when supply networks were under such strain as during the lockdown era when governments globally limited the free movement of products and services [56].

5.5. Theoretical Implications and Contributions

By evaluating the perspectives of construction experts, this research gathered the most essential variables about the influence of COVID-19 on the construction business. This research started by looking for previous studies that addressed situations comparable to the COVID-19 pandemic. The authors discovered that the construction industry is one of the industries most affected by the COVID-19 pandemic globally, and particularly in Sri Lanka, where project costs and schedules have been severely impacted, as most of these projects have been forced to halt due to the pandemic's spread. The authors relied on government reports and research advice in this regard, and then, they gathered the most important factors regarding the effect of COVID-19 on the construction industry in order to develop appropriate response strategies to mitigate these impacts and relaunch projects while providing protection and an appropriate environment for workers and stakeholders. In the discipline of construction management, researchers may build on the cost, schedule, health, safety, supply chain, and environment.

5.6. Managerial Implication

This study provides a comprehensive view of the most important factors that affect the construction industry due to the spread of the COVID-19 pandemic and, in turn, highlights the most important response strategies to mitigate these impacts, which organizations and policymakers can use to overcome the difficult time that the construction industry went through during the pandemic period. This study investigates the relationship between 'project and material related impacts' against 'materials, machines, money, manpower aids for existing projects', 'information and organizational-level aids', and 'additional projects and manpower' by using the PLS-SEM approach, which examines the latent relationship between variables and can help the project manager in the construction projects.

5.7. Limitations and Recommendations

Despite this study's substantial contributions, numerous shortcomings may be addressed in future research. This study was carried out in a developing nation, namely Sri Lanka. Hence, its findings can only be evaluated within the context of this study. Prospective investigations in other countries might be performed, and the findings can be compared to those obtained in this study. Second, this study examined the impact of COVID-19 on the Sri Lankan construction industry and effective reaction methods to alleviate these impacts. Additionally, this study employed a quantitative approach and collected data using a survey. Future research may take a qualitative method, or possibly a case study approach, to further understand apparent links. Third, due to budgetary restrictions and safety concerns, data for this study were obtained from a restricted number of Sri Lankan districts. Consequently, the findings of this study may not be generalizable to other Sri Lankan states. However, the data were collected through snowball sampling, and 123 respondents responded to the questionnaire. This includes organizations operating in the construction industry, whether owners, consultants, or contractors.

Additionally, there is no reason to believe that the respondents are distinct from those employed in other parts of Sri Lanka. Data from other nations' projects may be gathered and used in future research. Fourth, future scholars could compare this study's findings with works conducted in other countries and industries. Such data from other countries and industries can enrich the comparison and develop an understanding of COVID-19 impacts and response strategies. Fifth, the data in this study were collected through a questionnaire survey. Future works could use different methods to identify COVID-19 impacts and response strategies, such as by analyzing published scientific reviews. Finally, based on the study findings, future scholars could develop frameworks and tools for industry practitioners to select appropriate strategies to combat the impacts of COVID-19. In addition, future scholars could use other analyses, including model fit, and mediation analysis to analyze data in their studies.

6. Conclusions

Sri Lanka has faced many natural disasters and insecurity conditions as a nation over the last few decades. The COVID-19 pandemic has affected most industries with challenges, especially construction projects, which had the largest share of these risks. Most of these projects were suspended or delayed in delivery in most parts of the world, including Sri Lanka. The Sri Lankan construction industry must also choose not to panic because of the pandemic. Organizations should concentrate on micro-level issues rather than reacting to the overall impact with ad hoc actions. Strategies and operational choices must be properly integrated here. Organizations should concentrate on merging contexts rather than internal policies. Due to cost pressures, organizations must modify their strategic thinking to continue value-adding operations. Rather than synchronizing all initiatives simultaneously, Sri Lanka's construction industry must be aware of future development factors.

The model and findings of this research may be of substantial value and utility for academics, policymakers, and advocates in the building sector seeking empirical quantitative evidence and explanations of the COVID-19 consequences necessitating reaction solutions. A solid grasp of the ramifications of demanding reaction strategies is vital for effectively combatting the epidemic. Awareness of repercussions strongly related to response techniques could aid politicians and activists in designing response strategies that minimize the building industry's unfavorable effects. This study's primary contribution is establishing a quantitative model that explains how diverse impacts affect the requirement for a response plan in the construction industry.

The literature study in this study resulted in 12 impacts of COVID-19 on the construction industry in Sri Lanka. In return, response strategies that are expected to mitigate these impacts on project performances were identified. An EFA of the necessary impacts and response strategies was carried out. This resulted in a list of the most related impacts and responses that had the greatest impact. Consequently, six hypotheses were developed using the SEM-PLS analysis approach to explain the relationship between the impacts and responses and their analysis. It was clear from the results that four hypotheses, H1 to H4, were supported, and the loading coefficients were significant for most of the factors subject to this study.

The study achieved its objectives by focusing on the most important impacts of the COVID-19 pandemic, highlighting the most important response strategies that need to be implemented to save the construction industry from stagnation, and developing a model that explains the relationship between impacts and response strategies. This study is useful to the Sri Lankan government, construction organizations, contractors, and researchers in the field of construction management by developing more innovations and strategies that mitigate the impacts of COVID-19 on the construction industry.

Previous works have proven many similarities in the impacts of COVID-19 on the construction industry globally, with some peculiarities of each country. Hence, this study, which represents the case study in Sri Lanka, can be used to study the relationship between the impacts and response strategies. This research can be relied upon in future research to develop strategies that can be relied upon in the face of pandemics and emergencies that may work on the sudden stopping of construction projects and thus expose contractors and construction organizations to losses due to the delay in delivering these projects on time in addition to the lack of labor and the high cost of construction materials and transportation. Future researchers can also study the impacts of COVID-19 on cost and develop strategies for them separately from the impact on the project schedule. We suggest another research that includes the development of safety measures to reduce the impacts of COVID-19 on the workforce at construction sites.

Finally, the most prominent impacts of COVID-19 hazards on construction projects were schedule delays and cost overruns. Access difficulties, a shortage of labor, a lack of supplies, and the worry of the nearby neighbors all slowed construction progress significantly. The study presented numerous response strategies to improve the construction schedule. However, its effectiveness was reflected in the construction project's cost. The construction projects' pandemic prevention procedures incurred extra expenditures, such as medical supplies, COVID-19 testing, quarantine, and workplace cleaning.

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Institutional Review Board Statement: Ethical review and approval were waived for this study due to the fact that the study involves anonymous data collection.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to some data being proprietary or confidential in nature. Therefore, the data may only be provided with restrictions (e.g., anonymized data).

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Appendix A.

Table A1. COVID-19 impacts identified from the literature review and interviews.

Code	Pandemic Impact	Sources	Interview
CI1	Higher rejection rate of project financing	[57–61]	
CI2	Shortage of labor	[62–72]	/
CI3	Reduced number of public projects	[68,73–77]	
CI4	Downsizing of existing projects	[62,78–81]	/
CI5	Reduced morale among project team members	[82–86]	
CI6	Disruption in the supply chain	[68,75,77,87,88]	/
CI7	Termination of existing projects	[89,90] Interview	/
CI8	Shortage of materials	[63,68,91]	
CI9	Reduced number of private projects	[68,73–77]	
CI10	Reduced construction productivity	[65,92–95]	/
CI11	Reduced demand on construction-related works	[70,71,76,96,97]	
CI12	Reduced foreign investment in the construction industry	[96,98–100]	

Table A2. Response strategies of COVID-19 identified from the literature review and interviews.

Code	Response Strategies	Sources	Interview
CR1	Allow construction projects to work around the clock (24/7)	[75,77,101–108]	/
CR2	Facilitate the movement of workers from other industries to the construction industry (e.g., provide free training related to the construction industry)	[109]	
CR3	Have regular townhall sessions on COVID-19 policies and response mechanisms		/
CR4	Mandate COVID-19 as force majeure	[110]	/
CR5	Create a website on COVID-19 policies and response mechanisms	[91,101,102,104,105,111–113]	/
CR6	Form a special task force to provide support in maneuvering COVID-19 (ex. in terms of SOP guidelines, alternative procurement methods)	[75,91,105,108,113,114]	
CR7	Diversify existing supply chain	[77,91,101–103,106,115,116]	
CR8	Develop platforms to facilitate the generation of alternative revenues	[75,114,117]	
CR9	Initiate corporate social responsibility (CSR) programs targeting COVID-19	[91,114,118]	
CR10	Provide more financial aids (e.g., funding, grants, tax relief)	[91,107,114,115,117,119–121]	/
CR11	Facilitate the promotion of local construction materials		/
CR12	Restructure existing supply chain	[91,107,122]	
CR13	Ensure payments for public projects are on time	[91,107,114,115,119–121]	
CR14	Provide incentives to motivate individuals working at construction sites	[75,101–107,115,116,123]	/
CR15	Provide hands-on assistance in implementing SOPs at project sites	[114,124,125]	/
CR16	Provide help in digitalizing existing construction projects	[75,102,111,112,114,117,126]	
CR17	Develop employee assistance programs that fit all types of working groups	[109,121,127]	
CR18	Speed up the approval processes for construction work resumptions	[91]	
CR19	Mandate aids for construction loans (ex. defer loan payments, reduce interest rates, maintain liquidity access/credit provisions)	[91,107,114,115,117,119–121,128]	/
CR20	Implement the concept of a sharing economy	[101]	/
CR21	Provide infrastructure investment budgets to local governments	[91]	/
CR22	Benchmark COVID-19 policies and measures from other countries	[75,77,91,102,105,111,113,114,123,126,128]	

The Questionnaire Survey Used in This Study
COVID-19 impacts and response strategies on Sri Lanka's construction industry.

Appendix A.1. Respondent's Profile

Instruction: Please provide the following information.

Your type of organization:

1. Client (e.g., government, developers)
2. Consultant
3. Contractor
4. Others: __________

Years of experience in the construction industry:

5. Less than 2 years
6. 2–5 years
7. 6–9 years
8. More than 10 years

Most of your recent projects are:

9. Building construction (residential)
10. Building construction (non-residential)
11. Industrial construction
12. Infrastructure construction

Appendix A.2. Impacts and Response of COVID-19 on Sri Lanka's Construction Industry

Table A3. Please rate the criticality of the following COVID-19 impacts on Sri Lanka's construction industry.

COVID-19 Impacts	Criticality				
COVID-19 impacts in random order using online survey platform	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical

Table A4. Please indicate and rate any additional COVID-19 impacts on Sri Lanka's construction industry.

Additional COVID-19 Impacts	Criticality				
Additional COVID-19 impacts to be added by survey respondents	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical

Table A5. Please rate the criticality of the following response mechanism on Sri Lanka's construction industry.

Response Strategies	Criticality				
Response strategies in random order using online survey platform	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical

Table A6. Please indicate and rate any additional response mechanism.

Additional Response Strategies	Criticality				
Additional response strategies to be added by survey respondents	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical
	Not Critical	Slightly Critical	Moderately Critical	Critical	Not Critical

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