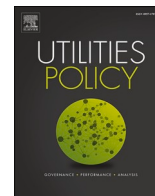




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Assessing the impact of COVID-19 and safety parameters on energy project performance with an analytical hierarchy process

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ABSTRACT

COVID-19 has destabilized the global economy, disrupted the lives of billions of people globally, and caused the workforce to suffer. Furthermore, the spread of this disease has caused most nations to impose strict lockdown regulations and shutdown most industries. This study aimed to highlight the key issues of energy project performance alongside construction activities that were halted during the COVID-19 outbreak to follow social distancing, lockdown, and public safety parameters. A questionnaire survey was administered to accomplish the purpose of this study. The responses of 42 energy project professionals and experts were evaluated using the analytical hierarchy process (AHP) for group decision-making. AHP shows that the biggest influences on project performance during COVID-19 pandemic were government measures and personal factors. The findings provide insight to support energy project planning and management during and after the pandemic, including prioritization of labor force health and safety.

1. Introduction

The global COVID-19 pandemic has become one of the key issues currently faced by the planet (Xuan Tran et al., 2020). The government's social distancing policy has had a devastating effect on multiple businesses (Sheth, 2020) and impacted people's lives in unprecedented ways (Fell et al., 2020). The COVID-19 pandemic has significantly challenged worldwide safety with respect to people's health (Buechler et al., 2020; Hosseini, 2020; Mofijur et al., 2021). Social interaction has changed in unusual ways (De Vos, 2020; Sovacool et al., 2020). The restriction on traveling and observing social distancing (Guan et al., 2020; Yezli and Khan, 2020), alongside the traveling restrictions within and outside countries, has undoubtedly affected the global economy (Poli et al., 2020). Most sectors, including services (Belhadi et al., 2020), are affected by the COVID-19 pandemic, especially the manufacturing and construction industry (Araya, 2021), subsequently affecting project performance and success rate. The most alarming feature of this crisis is long-term economic destruction and the potential long-lasting

destruction of energy project performance (Rye and Jackson, 2020). However, most stakeholders cannot continue the project activities because of government precaution policies to prevent the spread of COVID-19 (Cheng et al., 2020) as COVID-19 spreads person-to-person through close contact (Chu et al., 2020). Consequently, the stoppage of work on construction sites or limited access hugely impacts project performance and completion (Mahamid, 2013).

Most construction sites have limited human resources and activities to avoid the devastating situation of the pandemic. Consequently, construction workers have limited opportunities. The construction industry has stated higher closure rates compared to other industries. Globally, energy demands are growing, and several energy-related challenges are emerging; the COVID-19 pandemic has pushed construction industries to recommend energy development policies. Consequently, many energy projects are executed globally, but they encounter various hindrances and obstacles, which cause them to be stifled or postpone project completion (Araya, 2021).

Like other areas of the world, Pakistan has faced COVID-19 acute

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challenges in different areas of the country as the number of affected people grew. The growth of COVID-19 cases in Pakistan directly affects the construction of energy projects. The actions taken by the Government of Pakistan (GoP) are to delay the growth or roll out the curve of COVID-19, comprising the limited activities in the construction industry to follow standard operating procedures (SOPs) as instructed by the World Health Organization (WHO) (Pakistan, 2020). This situation has created immense uncertainty in energy project activities and tasks. However, the nature of COVID-19 and the lack of safe facilities for owners, contractors, and sub-contractors at construction sites may render several contractual obligations unachievable.

In the global COVID-19 condition, participants of construction contracts will be fretful regarding the commercial effect on their processes. In this manner, the challenges of in-progress project delivery and project execution are uncertain. Project performance is expected to be affected, as workers/labor are forced to adopt COVID-19 safety parameters, such as quarantines, social distancing, and self-isolation. Consequently, projects are delayed and construction work is disrupted. Hence, during the COVID-19 crisis, performance in any of the life-cycle project stages is likely affected. The potential consequence is a hike in potential claims, such as liquidated damages, time extension, and additional payment, as claimed by the contractor or sub-contractor.

Although many past studies have assessed the impact of COVID-19 on different sectors, there is a lack of empirical knowledge of COVID-19 connection to energy project performance. To the best of the authors' knowledge, no studies have explored the impact of the COVID-19 pandemic on construction energy project performance. Therefore, this study aimed to address this gap in the context of the Pakistani construction industry using the analytical hierarchy process (AHP) method. Energy projects suffering the most during this pandemic to meet schedules, quality, satisfaction, and budget necessitates great attention to ascertain project performance. The fundamental research questions focused on in this study comprise the following: a) How did the COVID-19 pandemic impact energy project performance? b) Does COVID-19 reduce energy project performance? c) What are the implications and strategies for increasing project performance during this pandemic?

The justification for this study stems from energy projects requiring serious consideration of policymakers to take a rationalized view considering the pandemic. Unless this issue is addressed, social distancing and safety parameters can lead to significant project delays and a negative impact on project performance. It is a preliminary step to investigate the impact of COVID-19 on energy project performance, which demands an in-depth analysis to define future policies and directions in pandemic situations.

2. Project performance overview

Time, quality, and cost have long been defined as elementary standards for evaluating project performance (Chan, 2001). These three parameters of project performance are identified as the iron triangle of time, cost, and quality, which is also called the "triple constraint" (Gilbert Silvius et al., 2017). Project performance is measured using an appropriate set of key performance indicators such as successfully execute the project on schedule, within the planned budget, with the highest quality, and the ability to meet end-user requirements (Berssaneti and Carvalho, 2015).

The project performance described in the current study is the torrent of advantages that occur as a consequence of executing the energy project. Failure to benefit from rapid and reasonable opportunities or end-user needs will lead to negative business consequences and a loss of market shares (Love and Edwards, 2004). For successful energy projects (Maqbool et al., 2020), various human resources, such as managers in the construction office and a labor force on the project job site, are required (Hussain et al., 2020). With the prospect of real progress of project work on job sites, schedule quality, and cost tendencies, the project owner should take timely remedial measures if any variations are

found. Human resources are the people who prepare an organization's labor force. These are the key persons who execute the project (Hussain et al., 2020) and improve the energy project performance. Effective control and management of the construction labor force will help achieve competitive project quality and cost-effectiveness (Demirkesen and Ozorhon, 2017). Owners, contractors, and subcontractors are usually concerned with labor activities at construction job sites. Labor productivity significantly influences project time and cost performance (Abdel-Razek et al., 2007). The COVID-19 pandemic has suspended the construction industry by delaying and stopping energy projects under development and disrupting labor scarcity due to quarantines (Araya, 2021; Associated General Contractors of America, 2020). In a pandemic, the project performance is severely affected by the SOPs enforced by the state, and a regressive analysis in this regard is required.

3. Impact of the COVID-19 pandemic

3.1. COVID-19 pandemic origin and impacts

Coronaviruses comprise a subfamily of viruses that move from animals to humans (Chen et al., 2020). The novel coronavirus is the third of its kind to be confirmed as a pandemic in the 21st century after severe acute respiratory syndrome (SARS), and the Middle East Respiratory Syndrome coronavirus (MERS), which were classified in the same category in 2003 and 2012, respectively, by the WHO (2019). On December 31, 2019, the WHO state workplace in China's Hubei province, confirmed symptoms of patients suffering from severe respiratory illness (Jia et al., 2020). Initially, the doctors diagnosed it as 'pneumonia' of unidentified etiology owing to the limited evidence obtainable regarding the reason for the illness. At the end of December 2019, Wuhan City, an emerging business center of China, faced an outburst of the novel coronavirus that ended the life of over 1800 terminally ill patients and affected more than 70,000 people in the first 50-days of the virus attack (Shereen et al., 2020). At first, it was considered that the patients sick with COVID-19-induced pneumonia in China could have gone to the seafood marketplace (Shereen et al., 2020). Furthermore, the WHO has confirmed COVID-19 as a universal pandemic because of its extensive spread, several deaths worldwide, and more illness and death rates than earlier coronavirus outbreaks. In June 2020, the WHO Director-General informed media channels concerning COVID-19 cases increasing globally.

3.2. Earlier studies on energy projects

In a pilot study conducted in China, Cheshmehzangi (2020) studied the effects of COVID-19 on domestic energy usage and the concentration on domestic energy effects during the COVID-19 outbreak. The author found that the COVID-19 outbreak and lockdown directly impacted transportation, cooking, entertainment, cooling, heating, and lighting. The COVID-19 pandemic may lead to lasting changes associated with the digitalization of jobs, thereby decreasing mobility and overall fossil energy usage (Kanda and Kivimaa, 2020). Werth et al. (2021) examined the effects of governmental limitations on electrical load, generation, and transmission in 16 European countries during the COVID-19 outbreak. The authors revealed that the energy load decreased during COVID-19 restrictions; effects were observed in power generation. Zhang et al. (2020) examined the influence of restrictive measures due to the COVID-19 outbreak on energy demand in different areas of Sweden. The economic concerns of the COVID-19 pandemic are widespread, with a contrary impact on renewable energy development. Abu-Rayash and Dincer (2020) researched the influence of the worldwide pandemic on the energy sector, employing the area of Ontario as a case study, and found a distinctive tendency of reciprocating energy demand during the study period. Siddique et al. (2020) conducted a study and discussed the unique effect of the COVID-19 outbreak on the global economy, particularly in the energy sector. Moreover, the authors

argued that the current challenges faced in water, air, and energy resources (renewables and non-renewables) are the substantial and correlated factors of the ecosystem.

Kulachinskaya et al. (2020) conducted a study in Russia through in-depth interviews of the energy sector crisis during the COVID-19 epidemic. The authors revealed the deviation of sectoral energy utilization dynamics, which translates into the essential aspect of the 2020 challenges in the energy sector. Pradhan et al. (2020) investigated the present and future effects of COVID-19 on India’s renewable energy sector. Hundreds of industries are disturbed because of the COVID-19 pandemic lockdown, and the energy sector is one of them. A recent study by Shafi et al. (2020) demonstrates that most contributing firms have been harshly disrupted. They are confronting numerous concerns, such as financial and supply chain disruption and a decline in demand, sales, and profit. Furthermore, more than 83% of firms neither had nor formulated any plans to control such circumstances. The restricted actions subsequently impact the energy sector, which intensifies energy demand problems (Zhang et al., 2020). Steffen et al. (2020) drew attention to the necessity of navigating the current condition without jeopardizing the vital clean energy transition under the COVID-19 outbreak.

3.3. Coronavirus pandemic and Pakistan’s situation

Pakistan is near the most-affected countries such as China, where the COVID-19 outbreak occurred for the first time (Waris et al., 2020). On February 26, 2020, Pakistan’s health minister declared the country’s first two confirmed cases of COVID-19. From March 2020, the number of verified cases have started increasing quickly. The current COVID-19 situation in Pakistan is presented in Fig. 1. The outbreak is heavy in provinces such as Sindh and Punjab. The death rate in Pakistan is 2%, and the recovery rate is 98% (Fig. 1), which is much better than that in several severely infected countries. To deal with the COVID-19 outbreak, the GoP commenced preventive measures such as public meetings, travel limitations, and compulsory quarantine for suspicious patients after taking the COVID-19 test. The GoP has also ordered the following SOPs because of the higher infection rate and growth in casualties. Pakistan enforced a four-month lockdown to reduce the COVID-19 growth. Due to the COVID-19 outbreak and lockdowns, Pakistani industries are facing record adverse effects on their businesses. However, researchers and investigators worldwide are sparing no endeavor on treatment for COVID-19 but suggest social distancing, which thus far is the only method of fighting COVID-19 (Huynh, 2020; Shereen et al., 2020).

]The SOPs recommended by the WHO have been implemented by the GoP to normalize the pandemic situation and save valuable lives;

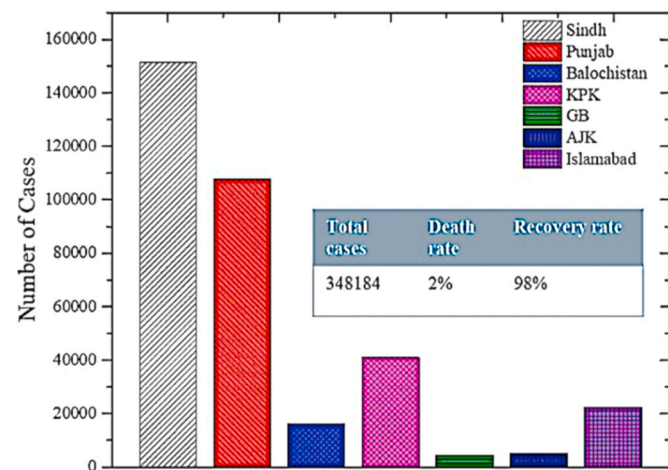


Fig. 1. COVID-19 in Pakistan (source: <http://covid.gov.pk/>) by Nov 2020.

however, this causes acute anxiety and panic among the people who are part of the energy projects. SOPs have limited workers from working on construction sites, or limited workers are allowed on-site (Araya, 2021). These situations have brought about an economic crisis in various sectors, along with construction energy projects and industrial projects. The construction area is significantly affected by the countrywide lockdown declared by the GoP because of COVID-19. Countrywide lockdowns have delayed energy projects due to the unavailability of laborers and workforces, construction materials, and machinery and problems in securing project funding (ETEnergyWorld, 2020a; 2020b). There is a robust struggle to adjust people’s behavior, predominantly through social distancing and “stay at home” policies (Krishnamurthy, 2020). The SOPs enforced in the construction sector affected the entire picture of the projects and created financial and human resource constraints.

4. Methodology

4.1. Analytical hierarchy process (AHP)

Saaty (1980) developed the AHP method, a robust, flexible multi-criteria decision analysis approach used to evaluate complex and unstructured problems in several decision-making situations (Saaty, 1990, 2008). This method also permits integrating quantitative and qualitative elements into decision-making practices (Liu et al., 2018). The key imperative measures in the AHP method are devising the assessment problem and building a hierarchy. After building the hierarchy, the decision-maker can rank the factors to determine the relative importance of the factors at each hierarchy level. Concerning their weight, factors are assessed at each level and compared pairwise. For the pairwise comparison, a 9-point relative importance scale is employed to make the judgments, and it generates a ranking. The AHP is a method applied for forming, quantifying, and synthesizing (Forman and Gass, 2001), wherein specialists and professionals are invited to give numerical quantifications through paired comparisons to determine the weights of pre-set measures (Falsini et al., 2012). AHP application approaches present a powerful technique for conducting subjectivities and uncertainties in construction practices and supporting the elucidation of multifaceted problems.

4.1.1. Establishment of pairwise comparison matrices criteria

Pair-wise comparisons from a square matrix are as follows: $(n \times n) A = \{a_{ij}\}$ ($1 \leq i, j \leq n$), where $a_{ij} \in \{1, 2, \dots, 9\}$ for $1 \leq i < j \leq n$, and n is the number of compared pairs of elements, the values of which are between 9 and $1/9$ and reversible pair-wise comparisons $n(n-1)/2$, design for $a_{ij} = 1/a_{ji}$. The diagonal elements of the matrix are equal to 1 using equations (1) and (2) (Liu et al., 2018).

$$A = \begin{pmatrix} a_{11} & a_{12} & \dots & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & \dots & a_{nn} \end{pmatrix} \quad (1)$$

$$a_{ji} = \frac{1}{a_{ij}} \quad (2)$$

4.1.2. Reliability and consistency index

The consistency ratio (CR) was verified to check the consistency of the comparison matrices. Reliability indices correspond to the maximum distinctive root λ_{max} . The resultant matrix geometric mean of all the elements in each row is obtained using equation (3) (Hussain et al., 2019; Liu et al., 2018).

$$W' = (w'_1, w'_2, w'_3, \dots, w'_n)^T = \left(\sqrt[n]{\prod_{j=1}^n a_{1j}}, \sqrt[n]{\prod_{j=1}^n a_{2j}}, \dots, \sqrt[n]{\prod_{j=1}^n a_{nj}} \right)^T \quad (3)$$

Each factor of the vector is standardized using equation (4) (Hussain et al., 2019).

$$W'W = (w_1, w_2, w_3, \dots, w_n)^T = \left(\frac{w'_1}{\sum_{i=1}^n w'_i}, \frac{w'_2}{\sum_{i=2}^n w'_i}, \dots, \frac{w'_n}{\sum_{i=n}^n w'_i} \right)^T \tag{4}$$

where, $w = (w_1, w_2, \dots, w_n)^T$ is the principal eigenvector corresponding to λ_{max} and can be ascertained using an iterative method. Moreover, the maximum eigenvalue is calculated using equation (5) (Al-harbi, 1999; Liu et al., 2018).

$$\text{Resultant matrix} = \lambda_{max} = \sum_{i=1}^n \frac{(AW)_i}{nw_i}, (AW'_i) \tag{5}$$

If A is entirely reliable, then the principal eigenvalue λ_{max} is equal to n . Thus, $Aw = nw$.

After obtaining λ , equation (6) (Al-harbi, 1999; Liu et al., 2018) can be used to verify the consistency index (CI).

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{6}$$

Likewise, the consistency ratio (CR) can be calculated via equation (7) (Al-harbi, 1999; Liu et al., 2018). The CR is acceptable, if it does not exceed 0.10.

$$CR = \frac{CI}{RI} (n \geq 2) \tag{7}$$

Finally, the random index (RI) depends on the number of decision possibilities. If $CR \leq 0.10$, the evaluation is consistent; otherwise, it needs to be reviewed.

4.2. Questionnaire design and content

The questionnaire was categorized into two main parts: the first part comprised general information regarding respondents. The second part contained the key-dependent and independent variables, as listed in Table 2. The independent variables of government measures have sub-variables such as enforcing social distancing (Z11), enforcing “stay at home” policies (Z12), and restricting the movement of citizens (Z13). The independent variables of personal factors have sub-variables of trying to avoid people (Z21), experiencing difficulties in the workplace (Z22), stressing about contracting coronavirus (Z23), and experiencing psychological problems (Z24) and financial weakness (Z25). The dependent variable is project performance with sub-variables such as pre-estimated budget (Y11), pre-defined schedule (Y12), satisfaction (Y13), and meeting the quality standard (Y14).

4.3. Data collection

In this study, the AHP method was used; 42 energy project

Table 1
Characteristics of the sample.

	Total Respondents	%age
Age		
30–35	12	28.57%
36–40	13	30.95%
41–45	11	26.19%
More than 45	6	14.29%
Work Experience		
1–10	14	33.33%
11–20	17	40.48%
Above 21	11	26.19%
Profession Cadre		
Chief engineer	10	23.81%
Executive engineer	14	33.33%
Project manager	18	42.86%

Table 2
Independent, dependent, and lower factors.

S. No.	Key dependent variable	Independent variable (mid-level)	Factors (Lower Level)
	Project Performance	COVID-19 Government Measures Personal Factors	<ul style="list-style-type: none"> • Pre-estimated budget • Pre-defined schedule • Satisfaction • Meet quality standard • Enforce social distancing • Enforce to stay at home • Strict movement of citizens • Tried to avoid people • Difficulties for workplace • Stressed to catch Corona Virus • Effect psychological health • Face financial weakness

practitioners were selected from the construction and energy industry in Pakistan, who have a wide variety of expertise and knowledge on the COVID-19 pandemic and energy projects. All practitioners were highly qualified; nevertheless, the essential ground of knowledge of energy projects or the COVID-19 pandemic was monitored to determine the acceptable outcomes of the research. A questionnaire was answered by a group of construction and energy project practitioners and experts, who presented their views on COVID-19 and energy project performance. Purposeful sampling was adopted to select energy project experts and professionals from the public construction industry in Pakistan in order to employ the group decision-making process via the AHP survey. The target respondents were chief engineers, executive engineers, and project managers who had obtained adequate professional experience to elucidate the relationships in this study.

The expert panel intended to perceive the importance of the variables using the AHP approach with 42 construction practitioners and professionals on the COVID-19 pandemic and project performance. A survey was conducted to collect data, in which experts and professionals were asked to score and rank the factors. The respondents were invited to complete the questionnaire based on their professional expertise and knowledge. Of the 42 respondents, 10 (23.81%) were chief engineers, 14 (33.33%) were executive engineers, and 18 (42.86%) were project managers. Participants had an average of 1–30 years of work experience; 14 (33.33%) had between 1 and 10 years, 17 (40.48%) had between 11 and 20 years, and 11 (26.19%) had more than 20 years of professional experience. Table 1 presents the sample and respondents’ characteristics.

4.4. Model of developed/adopted analysis (factors building technique)

COVID-19 and its impact on energy project performance: First, the dependent and independent variables were defined, as presented in Table 2. The dependent variable in the model is energy project performance, and the independent variable is COVID-19 and is given as a mid-level factor in the indexes for AHP modeling. Distinct sub-variables were used to evaluate the independent variables, considered lower-level elements in the AHP model. Moreover, the features are presented in the upcoming segments. This section examines the vital variables used in the current study, alongside the type of constructs.

5. Results and discussion

The AHP technique was employed to rank and compare the matrices. A total of 42 respondents ranked these factors. For ranking, a 9-point scale technique was used. Table 3 presents the relationship between i

Table 3
Matrix scale and ranking procedure judgment matrix.

No.	Rank	A _{ij}
1	i and j are equally important	1
2	i is a little more important than j	3
3	i is more important than j	5
4	i is significantly more important than j	7
5	i is extremely more important than j	9
6	i is a little less important than j	1/3
7	i is notably less important than j	1/5
8	i is highly less important than j	1/7
9	i is extremely less important than j	1/9

and j, and it clarifies the 9-point scale technique. The following segments explain the measures of expressing matrices and the testing procedure, comprising reliability.

5.1. Criteria for creating comparison matrix

The target respondents were requested to rank diverse factors for relationships to the dependent variable project performance and independent variables such as COVID-19 (government measures and personal factors). For the dependent variable “Project Performance,” there are three compressions; therefore, the authors created four matrixes for energy project performance. There are three comparisons of government measures and five comparisons of personal factors. Hence, we have three by three matrixes for government measures and five by five matrixes for personal factors. The diagonal elements of the matrixes are always 1, and only need to fill up the upper triangular matrix.

A pairwise comparison matrix is thus created using equation (1), as a_{ij} belongs to {9,8,7,6,5,4,3,2,1,1/2,1/3,1/4,1/5,1/6,1/7,1/8,1/9}, representing a pairwise judgment. Moreover, a_{ij} is equal to 1, where 1 ≤ i, j ≤ n.

5.2. Ranking elements for creating decision matrixes

We developed the average matrixes of project performance, government measures, and personal measure variables to illustrate the decision matrixes.

5.2.1. Project performance

Based on the responses of 42 respondents, the matrix was created for project performance, as presented in Table 4.

$$d1 = \begin{pmatrix} 1 & 2 & 3 & \frac{21}{5} \\ \frac{1}{2} & 1 & \frac{23}{4} & 3 \\ \frac{1}{3} & \frac{4}{23} & 1 & \frac{22}{7} \\ \frac{5}{21} & \frac{1}{3} & \frac{7}{22} & 1 \end{pmatrix}$$

Table 4
Matrix for project performance.

Project performance		a	b	c	d
a	Pre-estimated budget	1	2	3	21/5
B	Pre-defined schedule	1/2	1	23/4	3
C	Satisfaction	1/3	4/23	1	22/7
D	Meet quality standard	5/21	1/3	7/22	1

The resultant matrix of Y11, Y12, Y13, and Y14 relating X (Project performance) using equation (1).

5.2.2. Government measures

The following matrix was created by the responses of 42 respondents for government support, as presented in Table 5.

$$d2 = \begin{pmatrix} 1 & 3 & \frac{21}{2} \\ \frac{1}{3} & 1 & \frac{21}{6} \\ \frac{2}{21} & \frac{6}{21} & 1 \end{pmatrix}$$

5.2.3. Personal factors

Respondents’ responses were gathered for personal factors from 42 experts, and the following matrix was created, as presented in Table 6.

5.2.4. Reliability and consistency index

The consistency was tested from the above equations, and by employing the computations shown in Tables 4–6. When the value of CR is less than 0.10, the matrix is reliable and consistent; otherwise, it must be refreshed. As a result, the RI in Table 7 illustrates the variances in the different orders of the matrix. The ranking of priority variables and constructs defines the means of computing the CR, which is the ratio between the consistency index (CI) and RI (Saaty, 1990). According to the results obtained for the CR, key variables such as project performance, government measures, and personal factors were 0.077, 0.060, and 0.072, respectively. It can be seen that the CR values were less than 0.1, which verifies that all judgment matrices achieved consistency checks, and the outcomes were consistent for advancing and facilitating decision-making.

5.2.5. Ranking of factors

Factors assumed to influence the project performance via COVID-19, such as government measures and personal factors, were ranked by gathering the survey data and calculated outcomes. Tables 8–10 reveal the ranks of the analyzed factors and their outcomes.

Mathematical equation for evaluating energy project performance during COVID-19 pandemic and safety parameters.

Based on the influence values and the quantities of the factors, mathematical equation (8) (Hussain et al., 2019) for calculating project performance was composed as follows:

Set t³_i (=1, 2 12) is the final point for the twelve factors.

$$w_{ij}^2, w_{ij}^1 (i = 1, 2, \dots, m; j = 1, 2, \dots, n) \tag{8}$$

Utilizing the above formula, the relative impact value of i in the middle or lowest level compared to i at this level is calculated, and m and n are the total number of factors in this level and the level beneath it, respectively. Then, the score of the kth level relative to (k + 1) can be calculated using equation (9) (Hussain et al., 2019):

$$t_i^k = \sum_{j=1}^n w_{ij}^{k+1} t_j^{k+1} \quad (k = 3, 2, 1; i = 1, 2, 3, \dots, m) \tag{9}$$

After computing t_i in each level, the subsequent model can be employed to quantify project performance via equation (10) (Hussain

Table 5
Matrix for government measures.

Government measures		a	B	c
A	Enforce social distancing	1	3	21/2
B	Enforce to stay at home	1/3	1	21/6
C	Strict moments of citizens	2/21	6/21	1

The resultant matrix of Z11, Z12, Z13, concerning Y1 (Government measures) using equation (1).

Table 6
Matrix for personal factors.

$$d3 = \begin{pmatrix} 1 & 2 & 3 & \frac{21}{7} & \frac{21}{2} \\ \frac{1}{2} & 1 & 3 & \frac{21}{3} & 2 \\ \frac{1}{3} & \frac{1}{3} & 1 & \frac{22}{3} & \frac{21}{3} \\ \frac{7}{21} & \frac{3}{21} & \frac{1}{2} & 1 & \frac{16}{7} \\ \frac{2}{21} & \frac{1}{321} & \frac{3}{21} & \frac{7}{16} & 1 \end{pmatrix}$$

Personal factors	a	b	C	d	e
a Tried to avoid people	1	2	3	21/7	21/2
b Difficulties in workplace	1/2	1	3	21/3	2
c Stressed about contracting coronavirus	1/3	1/3	1	2	21/3
d Experience financial weakness	7/21	3/21	1/2	1	16/7
e Affected psychological health	2/21	1/321	3/21	7/16	1

The resultant matrix of Z21, Z22, Z23, Z24, and Z25 regarding Y2 (personal factors) using equation (1).

et al., 2019).

$$W = \frac{1}{10} \sum_{i=1}^3 t_i^1 \times 100\% \tag{10}$$

In equation (10), t_1^1, t_2^1, t_3^1 are the ranking values for government measures (Y1) and personal factors (Y2) relative to project performance (X). W is the total project performance score.

COVID-19 has demonstrated a destructive effect on everyday life, restricting social interactions, construction work on sites, and other activities globally (Jain and Vaishya, 2020). This study revealed a significant relationship between COVID-19 crises and energy project performance. Based on the results, the government’s decisions to suppress COVID-19 have severely affected energy project performance in Pakistan.

The ranking and weights of the matrices revealed that it is necessary to adopt precautions in the first stage of the COVID-19 pandemic as the workforce is involved in the execution of the energy project. However, owing to health precautions, such as social distancing, lockdown, and the spread of COVID-19, construction workers stop working. During this epidemic, the most common problems confronted by construction were human performance and involvement problems, whereas there were also problems associated with the economy, budgeting, policy, and allocation of resources. In such a situation, further problems occur, such as with site access and traveling. Most energy projects have discontinued working on sites, generally aiming to restart in the future. Moreover, the study found that the expansion of COVID-19 has mostly been disruptive and will likely continue to disrupt the energy project’s budget and schedule.

Furthermore, we found that lockdowns due to the COVID-19 pandemic in the country have limited movement, decreased labor force availability in the market, stopped manufacturing processes, and

Table 7
Random consistency index.

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Note: n = order of matrix.

suspended all construction activities on job sites. Moreover, we found that laborers’ avoidance of people was one of the most challenging factors during the COVID-19 outbreak. Social distancing and strict policies on movement that aim to stop the expansion of COVID-19 may influence the number of construction workers allowed on construction sites. The degree of possibility that construction workers suppose when working on energy projects will be directly associated with how many labor contacts exist across the construction activities. In this scenario, construction workers are unwilling to work during the COVID-19 pandemic on the job site.

This study contributes to the energy project literature by incorporating the COVID-19 pandemic and energy project performance, which has not been given much attention in previous studies. Our findings reveal that safety measures and responding to the current challenges of COVID-19 are related to energy project performance. The findings of this study reveal the adverse impact of the COVID-19 pandemic on energy project performance. The study variables were validated, and they were found to be reasonable and reliable through a series of statistical analysis tests using first-hand data from empirical cases. This study reveals how COVID-19 can impact time, cost, quality, and satisfaction by revealing the devastating effect of COVID-19 on construction project performance.

Regarding practical contribution, this study provides insight into the construction sector, especially energy projects that are faced with challenges by the COVID-19 pandemic. Furthermore, this study revealed that the pandemic and construction workers follow the safety parameters imposed by the government, which decreases the performance of energy projects. Therefore, project authorities should try to improve construction project performance during this pandemic and mitigate the

Table 8
Comparison of factors while ranking project performance.

Project Performance	Criteria Weight	Rank
Pre-estimated budget	0.41	1
Pre-defined schedule	0.30	2
Satisfaction	0.16	3
Meet quality standard	0.11	4
Total	1	

Table 9
Comparison of factors for government measures.

Government measures	Criteria Weight	Rank
Enforce social distancing	0.566	1
Enforce to stay at home	0.264	2
Strict moments of citizens	0.170	3
Total	1	

Table 10
Comparison of factors contribution personal factors.

Personal Factors	Criteria Weight	Rank
Tried to avoid people	0.345	1
Difficulties in workplace	0.264	2
Stressed about contracting coronavirus	0.164	3
Experience financial weakness	0.131	4
Affected psychological health	0.097	5
Total	1	

negative impacts related to the energy project performance. Our findings also imply that workers should have sound knowledge and information regarding the safety parameters of the COVID-19 pandemic to overcome the situation. Therefore, the authorities and legislative bodies should design emerging policies that could help the project executor (worker), thus ensuring a safe environment and conditions at the job site. Project authorities should convince the workers to take part in the execution phase while safely using safety parameters that reach the project purpose. Our findings can be employed as a reference for construction authorities and project planners, offering direction for strategies alongside the initial direction for concentrating, executing, and controlling the most substantial factors that influence project performance.

The current study suggests that contracting parties should thoroughly reconsider the terms and conditions of their contracts. Moreover, contractual terms must be followed to adopt the situation and establish the rights and claims of both contractual parties regarding extending the respective contract validity time and entitlement to extra payment during the delays. Generally, when the energy projects are behind schedule, the project is prolonged and pays extra project costs (Manzoor Arain and Sui Pheng, 2005). Therefore, many decisions should not be based exclusively on the initial contractual terms and conditions in such a situation.

6. Conclusions

The COVID-19 pandemic has been devastating in Pakistan and nations worldwide. Consequently, world economies have been overwhelmed, which is anticipated to have a critical effect on energy project policies worldwide. Although several studies have already been conducted on this topic, there are few studies on the impact of COVID-19 on energy project performance. Therefore, this study aimed to investigate the effect of the COVID-19 pandemic and safety parameters on project performance and address this knowledge gap.

After the implementation of social distancing and lockdown in the country, the study found that the COVID-19 raised numerous issues, such as energy project delays, on-job site construction problems, labor-force challenges due to restrictions imposed by the government, and project-cost escalation. The COVID-19 pandemic can trigger extensive labor interference, causing the potential unavailability to execute the project on job sites, leading to schedule suspensions and work re-sequencing. Such work disorders may influence project performance alongside the well-organized and quality progression of the work. Furthermore, this initial experience with the COVID-19 critical situation pointed out the construction industry's project performance problems in the areas of human, engineering, technical support, and economic resources.

COVID-19 directly impacts project performance, as construction activities challenging to perform virtually. Based on our findings, different policy measures are recommended to help project planners and managers mitigate the effects of the pandemic. The health safety of the construction labor force and the work environment are key priorities during and following a pandemic. Construction practitioners should plan for worker safety, so that construction projects can be accomplished as planned. Project planners and managers should also increase the involvement of project execution laborers in project activities, ultimately reducing the spread of COVID-19. Additionally, project managers and their contractors should reconsider and modify their safety plans related to COVID-19. Therefore, attention must be paid to reviewing every construction project to understand how to tackle suspensions, delays, and deteriorating performance.

Moreover, construction project stakeholders should be attentive, cautious, and proactive in finding ways to overcome uncertain situations. The findings demonstrate that the COVID-19 pandemic should be considered as a force majeure risk beyond the control of the contractual stakeholder, which averts the contractor from fulfilling the agreements

on schedule, within budget, and achieving other project objectives. As contractors and subcontractors are usually responsible for establishing construction site safety parameters, it is recommended that the owner take responsibility for the verification and proper implementation of SOPs designed by the government and health department.

Declaration of competing interest

No potential conflict of interest was reported by the authors.

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List of Abbreviations

AHP	Analytical Hierarchy Process
COVID-19	Coronavirus disease of 2019
SARS	Severe Acute Respiratory Syndrome
MERS	Middle East Respiratory Syndrome
WHO	World Health Organization
GoP	Government of Pakistan
SOPs	Standard Operating Procedures
CR	Consistency Ratio
CI	Consistency Index
RI	Random index
AW	Eigenvalues and eigenvectors (A is a consistent matrix, W is the principal eigenvector)

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