Critical Challenges of Quality Assurance of Cross-border Construction Logistics and Supply Chain During COVID-19 Pandemic: An International Expert Survey

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Abstract
Quality Assurance (QA) is a critical tool for the success of projects under cross-border construction logistics and supply chain (Cb-CLSC). However, the coronavirus (COVID-19) pandemic has imposed challenges that have affected the adequacy of QA of Cb-CLSC, and this has received limited attention in scholarly reports. Thus, this study aims to identify the critical challenges of QA of Cb-CLSC amid the pandemic by conducting an international expert survey with 102 experts across 25 economies/countries. Sentiment analysis is performed further to understand how the critical challenges have influenced the QA of Cb-CLSC using the negative-neutral-positive model. The study's finding identified ten critical challenges of QA of Cb-CLSC amid the COVID-19 pandemic, with the top five critical challenges comprising "shortage of raw construction material", "changes in work practices", "halting of operations and site closure", "heavy workloads and shortage of construction workers", and "design changes". Aside from the negativity imposed by the pandemic, the sentiments on each critical challenge portrayed positivity and neutrality that empowers the industry, denoting that the pandemic comes with opportunities that may be harnessed to position the QA of Cb-CLSC to be adequate for the post-pandemic era and endure the risks of future pandemics. This study contributes theoretically and practically by identifying and creating awareness of the critical challenges of the QA of Cb-CLSC. This could help practitioners, researchers, and policymakers develop a resilience framework based on innovative management strategies to position the QA of Cb-CLSC adequately for the post-pandemic era and endure the risks of future pandemics.

Keywords
COVID-19, Critical Challenges, Cross-border Construction Logistics and Supply Chain, Sentiment Analysis, Quality Assurance

1. Introduction

Cross-border Construction Logistics and Supply Chain (Cb-CLSC) consists of the interrelated activities and processes engaging contractors, suppliers, or vendors between countries/economies where one performs construction services in the other country/economy (Mawhinney, 2008). Assuring the quality of projects, termed quality assurance (QA), is a critical tool for the success of projects under Cb-CLSC as it guarantees confidence in the projects to meet pre-stated quality standards and perform satisfactorily during the entire service life (International Organisation for Standardisation [ISO], 1994). However, the complexity of performing QA of Cb-CLSC has worsened due to the coronavirus (COVID-19), which was introduced as a pandemic in March 2020 (World Health Organisation [WHO], 2020). Though COVID-19 mitigation measures have helped achieve steady recovery (Office for National Statistics [ONS], 2021; Eurostat, 2022), they have also impeded the movement between countries/borders/economies during QA of Cb-CLSC; hence, disrupting the construction supply chain. This is due to the stringent mitigation measures, including, e.g., social distancing, Lockdown, travelling restrictions, and limited workplace capacity (Organization for Economic Co-operation and Development [OECD], 2020). This has affected the quality of work performed on construction sites toward the overall project quality. For example, relating the quality of construction products to construction output, the ONS (2021) recorded a fall of 12.5% in construction output in 2020 compared with 2019.

The academia, in collaboration with the industry, has reported on the impact of COVID-19 on the construction industry from several perspectives. For instance, studies, including Ogunnusi et al. (2021), Raoufi and Fayek (2022), Dobrucali et al. (2022), and Kukoyi et al. (2022) identified the challenges imposed by the pandemic on the construction industry, but they focused on the general construction industry, which consists of several areas which have experienced unique challenges imposed by the pandemic. As such, Pamidimukkala et al. (2021) considered the impact of the pandemic on the construction health and safety of the workforce and identified the unique challenges but was based on conceptual analysis. Another critical area in construction to consider amid the pandemic is QA, and this has received limited attention. For instance, Ghansah et al. (2022) investigated how COVID-19 mitigation measures have impacted the QA of Cb-CLSC by performing a conceptual analysis. However, the unique critical challenges of the QA of Cb-CLSC amid the pandemic were not clearly explored. Meanwhile, identifying these critical challenges could contribute to developing a resilience framework to position the QA of Cb-CLSC to be adequate for the post-pandemic era and endure the risks of future pandemics.

This study, therefore, aims to empirically identify the critical challenges of QA of Cb-CLSC amid the COVID-19 pandemic by conducting an international expert survey across the globe. Sentiment analysis is performed further to understand how the critical challenges have influenced the QA of Cb-CLSC using the negative-neutral-positive model. The findings of this study could assist the practitioners and policymakers in developing a resilience framework capable of positioning the QA of Cb-CSLC adequately for the post-pandemic era and enduring the risks of future pandemics. This study also contributes to knowledge by identifying the critical challenges of QA of Cb-CLSC amid the pandemic and their associated sentiments. This may guide researchers to study QA in the construction industry further and suggest ways to improve the tool to survive future pandemics.

2. Brief Overview of COVID-19 on QA of Cb-CLSC

Conducting QA of Cb-CLSC depends on an organisation's quality management system, which embraces organisational resources, structure, and procedures (ISO, 1994). Integrating QA into the construction processes of organisations in Cb-CLSC regulates the processes' conduct and prevents side-stepping or deviation from quality requirements (Chung, 2002). QA of Cb-CLSC has been the responsibility of the contractor, consultant, designer, and government-authorised agencies. Hence, a concerted effort is central to ensuring an effective QA of Cb-CLSC by ensuring that everyone in the organisation knows what they are expected to do and what their colleagues are doing (Chung, 2002). In the case of the Cb-CLSC, the consultant, the client representative, and the government-authorised agency may need to travel offshore to foresee the quality of construction projects. Such a case has been the modular construction, specifically between Guangdong Province of China and Hong Kong, where authorised and client representatives are dispatched offshore to verify and accept the quality of modular components (Lu et al., 2022).

The construction industry is noted to be significantly affected by COVID-19, especially the QA processes, putting experts at high risk of severe infections. Baker et al. (2020) reported that, in April 2020, 8.3% of the 5.9 million construction workers, including QA teams, etc., were exposed once a month during the pandemic. Subsequently, this led to delays and suspension, cancellation of projects, supply chain disruption, creation of new risks, etc. This has raised a greater consent on QA of Cb-CLSC, which engages contractors and other professionals between countries/borders/economies where one performs services in the other country/economy. As such, the unique challenges imposed by the pandemic can be identified to inform decision-making in developing a resilience framework capable of positioning the QA to be adequate for the post-pandemic era and endure the risks of future pandemics.

3. Research method

The study adopted a quantitative research design following four research processes, as illustrated comprehensively in Figure 1. After a comprehensive desk literature review through google scholar, web of science, and Scopus (Ghansah et al., 2022), the identified potential challenges (18) were further refined by conducting a pilot test with experts, which helped settle on ten potential challenges, as shown in Table 1. These were finally presented to the experts across the globe via an online expert survey (using *QUALTRIC XM*) to respond to the questionnaire using the Likert scale: level of agreement (1=Strongly disagree; 2=Disagree; 3=Neutral; 4=Agree; 5=Strongly agree) and level of sentiment (1=Negative; 2=Neutral; 3=Positive). The population included experts from academia and the industry who are knowledgeable about QA processes in construction. Due to the lack of a recognisable database consisting of the population, the study adopted purposive sampling and snowball sampling techniques. As a result, experts were contacted via the Linkedin platform, email addresses, and company websites. Subsequently, after three months of data collection, 102 experts' responses were collected online across different countries/borders/economies.

Table 1: Potential challenges of QA of Cb-CLSC amid the pandemic

Code	Challenges	References
C1	Collaboration and communication difficulties	Oo et al. (2021); Rankohi et al. (2022)
C2	Long approval process and schedule delays	Oey and Lim (2021); Aigbavboa et al. (2022); Dobrucali et al. (2022) Rankohi et al. (2022); Olatunde et al. (2022); Rehman et al. (2022)
C3	Heavy workloads and shortage of skilled construction workers	Pamidimukkala et al. (2021); Oo et al. (2021)
C4	Legal issues due to a breach of contract terms and conditions	Bsisu (2020), Husien et al. (2021); Amoah et al. (2021); Radzi et al. (2022) Rankohi et al. (2022); Umar (2022)
C5	Working with masks difficulties	Oey and Lim (2021)
C6	Design changes	Oey and Lim (2021); Simpeh et al. (2022); Rankohi et al. (2022)
C7	Shortage of raw construction material	Rankohi et al. (2022); Jeon et al. (2022); Al-Mhdawi et al. (2022); King et al. (2022); Agyekum et al. (2022)
C8	Halting of operations and site closure	Rankohi et al. (2022); Aigbavboa et al. (2022)
C9	Rising cost of construction materials	Ogunnusi et al. (2021); Husien et al. (2021); Rehman et al. (2022)
C10	Changes in work practices	Oey and Lim (2021); Simpeh et al. (2022); Rankohi et al. (2022).

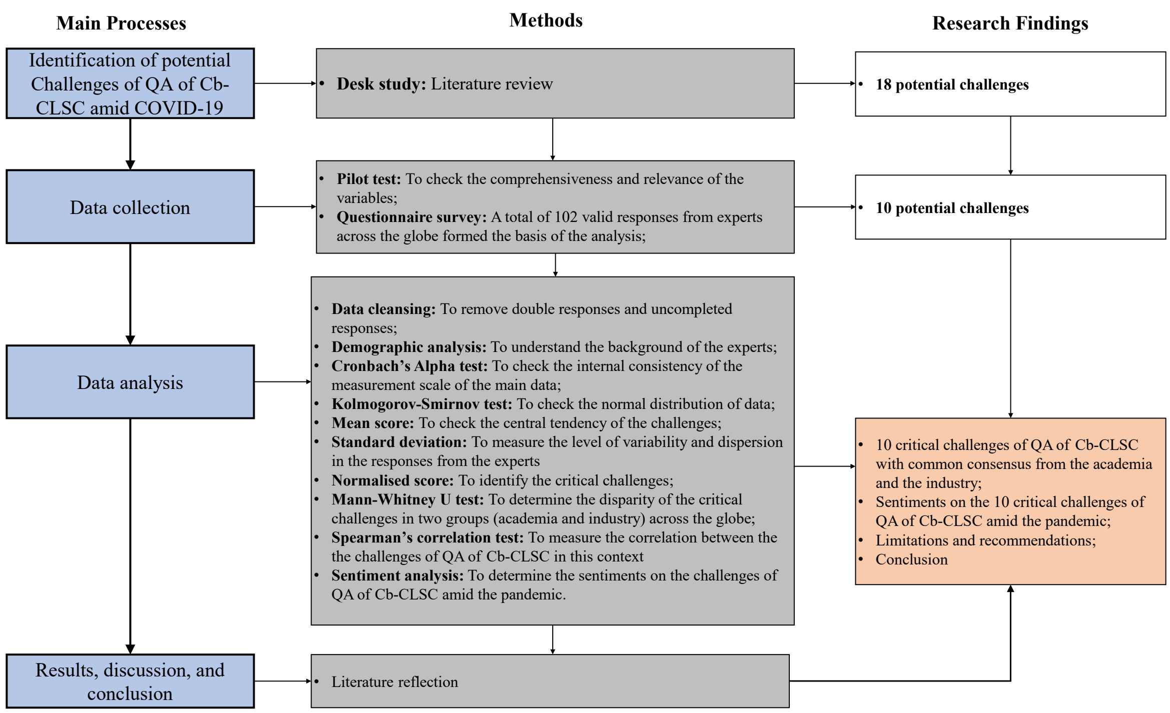

Figure 1: Research Flow

4. Data Analysis and Results

4.1 Analysis of Demographic Data

Figure 2 shows the countries/economies involved in the expert survey, with Ghana(n=37) having the most responses, followed by the United States of America (n=13). Twenty-five (25) countries/economies participated in the expert survey, and the responses were fairly generated across the continents, involving experts with backgrounds as detailed and analysed in Table 2.

Table 2: Experts' Profile

Variables	Frequency	Percentage (%)	Cumulative percentage (%)
Qualifications			
Bachelor of science (BSc)	12	11.8	11.8
Masters of Science/Philosophy (MSc/MPhil)	49	48.0	59.8

Doctor of Philosophy (PhD)	34	33.3	93.1
Other[a]	7	6.9	100.0
Sector			
Academia	47	46.1	46.1
Industry	55	53.9	100.0
Nature of Organisation			
Contractor	18	17.6	17.6
Consultancy	27	26.5	44.1
Academia	42	41.2	85.3
Other[b]	15	14.7	100.0
Total	**102**		
Profession			
Academician	45	44.1	44.1
Quality Auditor	2	2.0	46.1
Quality Engineer	10	9.8	55.9
Quality Control Manger	3	2.9	58.8
Authorised person from the government	3	2.9	61.8
Client representative	14	13.7	75.5
Other[c]	25	24.5	100.0
Experience			
Less than 5 years	45	44.1	44.1
5-10 years	25	24.5	68.6
11-20 years	23	22.5	91.2
21-30 years	3	2.9	94.1
More than 30 years	6	5.9	100.0

Other[a] may consist of other qualifications such as Higher Diploma certificate, and others
Other[b] may consist of government agency, etc.
Other[c] may consist of other experts essential in the QA process, including the construction and project managers

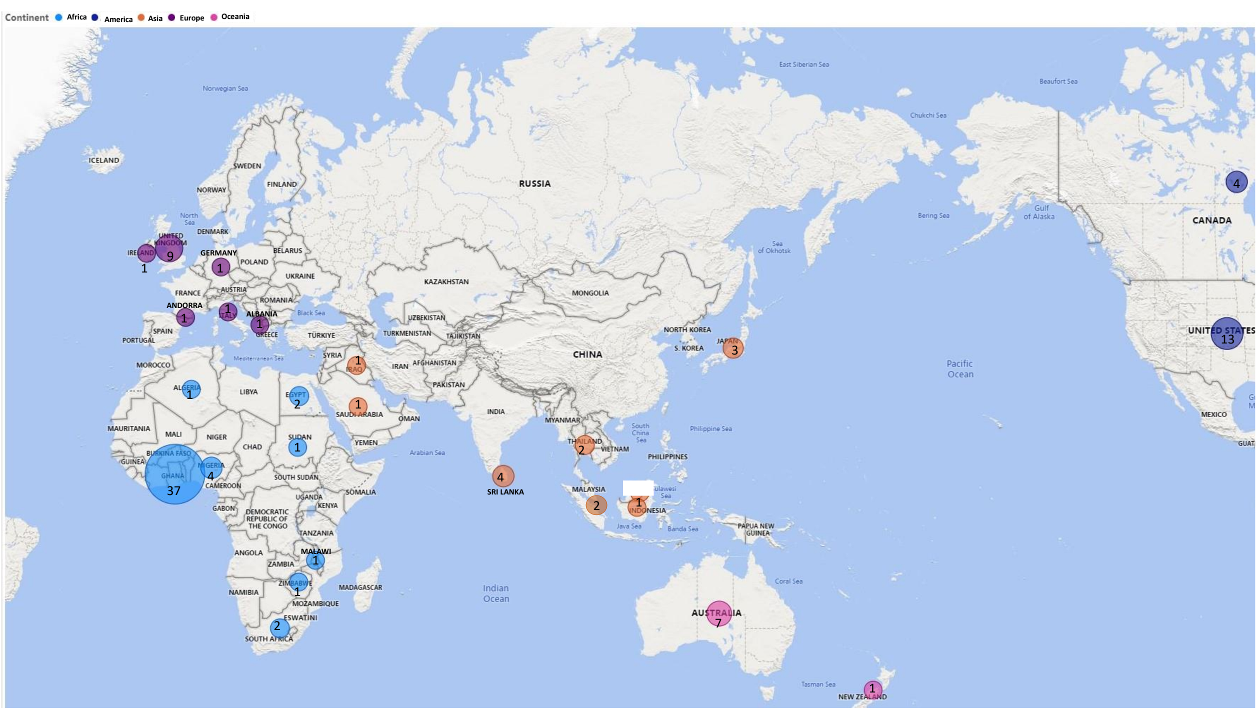

Figure 2: Participating Countries/Economies

Table 3: Normality Test, Descriptive Test, Level of Criticality test, and Differential Test

Code	Overall				Industry			Academia			K-S			Mann-Whitney U		
	Mean	SD	Ns	Rank	Mean	SD	Ns	Mean	SD	Ns	K-S stat.	P-value	U stat.	W	Z	P-value
C1	3.84	1.02	0.71[a]	9	3.76	1.07	0.69	3.94	0.97	0.65	0.28	0.00	1192.50	2732.50	-0.71	0.49
C2	4.14	0.81	0.71[a]	8	4.11	0.85	0.70[a]	4.17	0.76	0.59	0.24	0.00	1262.50	2802.50	-0.22	0.83
C3	4.01	1.19	0.75	4	3.80	1.25	0.70[a]	4.26	1.07	0.82	0.32	0.00	982.00	2522.00	-2.23	0.03***
C4	3.53	1.92	0.63	10	3.45	1.15	0.61	3.62	1.24	0.66	0.19	0.00	1188.50	2728.50	-0.72	0.47
C5	3.86	1.03	0.72	6	3.89	0.92	0.63	3.83	1.17	0.71	0.24	0.00	1282.00	2822.00	-0.07	0.94
C6	3.90	0.93	0.73	5	3.87	0.94	0.62	3.94	0.92	0.74	0.20	0.00	1243.50	2783.50	-0.35	0.73
C7	4.37	0.87	0.79	1	4.25	0.95	0.75[a]	4.51	0.75	0.84	0.33	0.00	1101.00	2641.00	-1.45	0.15
C8	4.51	0.63	0.75	3	4.49	0.61	0.75[a]	4.53	0.65	0.77	0.36	0.00	1223.00	2763.00	-0.53	0.59
C9	4.41	0.75	0.71[a]	7	4.45	0.72	0.73	4.36	0.79	0.68	0.35	0.00	1225.50	2353.50	-0.51	0.61
C10	4.10	0.91	0.77	2	4.16	0.81	0.72	4.02	1.01	0.76	0.238	0.00	1221.50	2349.50	-0.51	0.61

Note: Ns=Normalisation score=(actual mean–minimum mean)/(maximum mean-minimum mean), only normalisation scores ≥0.5 are deemed critical by the experts; SD=Standard deviation; W=Wilcoxon; Ranking based on the normalised score; P-value (Asymp. Sig. (2-tailed)≤0.05; degree of freedom for KS(df)=102 for all variables; [a]Equal normalised score, wherein challenges with low SD is ranked higher; ***challenge with p-value less than 0.05; H_o rejected, K-S= Kolmogorove-Smirnov[a]

Table 4: Spearman's Correlation Test and Sentiment analysis

Code	Spearman's Correlation										Sentiment Analysis				
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Negative (%)	Neutral (%)	Positive (%)	Sentiment score	P-values
C1	1.000										54.90	32.40	12.70	1.58	0.66
P-value	-														
C2	0.403**	1.000									61.80	22.50	15.70	1.54	0.56
P-value	0.000	-													
C3	0.490**	0.647**	1.000								60.80	26.50	12.70	1.52	0.59
P-value	0.000	0.000	-												
C4	0.536**	0.511**	0.604**	1.000							33.30	49.00	17.60	1.84	0.63
P-value	0.000	0.000	0.000	-											
C5	0.539**	0.453**	0.702**	0.573**	1.000						54.90	31.40	13.70	1.59	0.61
P-value	0.000	0.000	0.000	0.000	-										
C6	0.556**	0.321**	0.365**	0.421**	0.331**	1.000					47.10	42.20	10.80	1.64	0.32
P-value	0.000	0.001	0.000	0.000	0.001	-									
C7	0.320**	0.297**	0.467**	0.273**	0.526**	0.602**	1.000				62.70	22.50	14.80	1.52	0.86
P-value	0.001	0.002	0.000	0.005	0.000	0.000	-								
C8	0.352**	0.176	0.149	-0.009	0.173	0.323**	0.446**	1.000			55.90	12.70	31.40	1.75	0.62
P-value	0.000	0.076	0.134	0.929	0.082	0.001	0.000	-							
C9	0.459**	0.337**	0.354**	0.187	0.408**	0.526**	0.515**	0.575**	1.000		53.90	32.40	13.70	1.60	0.89
P-value	0.000	0.001	0.000	0.059	0.000	0.000	0.000	0.000	-						
C10	0.306**	0.546**	0.465**	0.307**	0.537**	0.178	0.275**	0.195*	0.418**	1.000	42.20	29.40	28.40	1.86	0.52
P-value	0.002	0.000	0.000	0.002	0.000	0.073	0.005	0.050	0.000	-					

P-values based on the Mann-Whitney U test to check the degree of association between the sentiments based on the two groups (academia and industry); ρ=correlation coefficient; **correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

4.2 Analysis of Main Data

The internal consistency of the data was determined first by Cronbach's Alpha (CA) following the thumb rule by Pallant (2001): CA value <0.60 is unacceptable, 0.60-0.80 is moderate and acceptable, and 0.80-1.00 shows excellent and higher internal consistency and validity of the data. The CA value for this study was estimated to be 0.87 for the level of agreement and 0.90 for the level of sentiment, connoting high internal consistency among the datasets. The Kolmogorov-Smirnov (K-S) adopted for this study denoted the dataset not to be normally distributed largely; hence, the dataset was deemed non-parametric. The central tendency of the challenges was measured using the means score, whilst the degree of variation among the experts' responses was determined using the standard deviation. The level of criticality of the challenges was then determined by using the normalisation scores following the thumb rule: normalised scores $\geq$0.50 are considered more critical (Adabre et al., 2020). Mann-Whitney U (MWU) test was then conducted to assess the degree of association among the experts' responses to the critical challenges based on their level of agreement from the viewpoints of academia and the industry (differential test). With this, a null hypothesis, H_0, is that there is no significant difference vis-à-vis the level of agreement on the critical challenges among academia and industry. The H_0 can be rejected if P-value is $\leq$0.05. The results are shown in Table 3.

Spearman's correlation test was conducted due to the non-parametric nature of the dataset to measure how the critical challenges correlated among themselves based on experts' responses, following the thumb rule: +1=perfect positive correlation, -1=perfect negative correlation, situated at a statistical significance of p-value$\leq$0.05. Sentiment analysis was finally conducted to understand the influence of the challenges on the QA of Cb-CLSC based on the experts' views using the negative-neutral-positive model (Ferrara and Yang, 2015), as shown in Table 3. The sentiment scores are estimated to determine the central tendency of the critical challenges in terms of sentiment level using the mean score. Finally, the degree of association between the sentiments on the critical challenges from experts in academia and industry is determined using the MWU test, setting a null hypothesis, H0, that there is no significant difference in the sentiments as responded by the experts from academia and industry. For the results, refer to Table 4.

5. Discussion of Results

The COVID-19 pandemic has disrupted the QA of Cb-CLSC by imposing challenges, making the QA processes difficult and cumbersome for experts. The study has then revealed the critical challenges of the QA of Cb-CLSC amid the pandemic, which has been missing from recent scholarly reports. The findings revealed that the associated challenges facing the QA of Cb-CLSC amid the pandemic include the challenges coded C1 to C10. Based on the mean score, the challenge having the highest value representing the central tendency of the experts is "halting of operations and site closure (C8)" (means score=4.51), followed by "rising cost of construction materials (C9)" (means score=4.41) and "long approval process and schedule delays (C2)" (means score=4.14). However, the mean score analysis does not identify the critical challenges. By estimating the normalisation scores for each challenge, the study identified the critical challenges of QA of Cb-CLSC following the thumb rule by Adabre et al. (2020). The study revealed all ten challenges to be critical. However, the top five critical challenges that need to be given attention by experts include "shortage of raw construction material (C7)" (score=0.79), "changes in work practices (C10)" (score=0.77), "halting of operations and site closure (C8)" (score=0.75), "heavy workloads and shortage of construction workers (C3)" (score=0.75), and "design changes (C6)" (score=0.73). The disruptions in the construction supply chain due to the pandemic cause a reduction/shortage in the raw construction material supply due to the multiple national lockdowns (Al-Mhdawi et al., 2022; King et al., 2022). The disruption occurs at the upstream supply chain, which may cause delays in the flow of construction materials to sit, halting the construction works till materials are available on site (Rankohi et al., 2022). This then affects the QA processes because the project may be delayed until the quality auditors carry out their functions, or they may rush to audit works quickly, which may be associated with errors because of speedy work delivery. The result of this study then affirms the study by Rankohi et al. (2022) and Jeon et al. (2022) when they revealed the shortage of materials on sites as a major challenge in the construction industry amid the pandemic. Also, from the individual sector perspective, the experts in academia regard the "shortage of raw construction material" as the most critical challenge, while the industry considers the "shortage of raw construction material" alongside "halting of operations and site closure". Subsequently, the study makes a proposition that the top most critical challenge of QA of Cb-CLSC is the "shortage of raw construction material", and this can replicate to cause other critical challenges, such as "halting of operations and site closure" and "changes in work practices". Overall, all the challenges (C1-C10) can be regarded as critical in impacting the QA of Cb-CLSC.

A further analysis using the Mann-Whitney U test denoted that the experts from academia and industry have no differences on the critical challenges except for the "heavy workloads and shortage of skilled construction workers" (C3) (P-value=0.03). This may be because the industry may regard C3 as a critical challenge of QA of Cb-CLSC amid the pandemic, but academia may have a different perspective on C3. From different perspectives, it is important to acknowledge that during the pandemic, the number of workers on construction sites was cut off compared to the typically required number due to the COVID-19 mitigation strategies such as social distancing on sites and the required number of workers in a workplace (Minett, 2020; Raoufi and Fayek, 2022). This affects the QA because it is process-oriented and requires the collective efforts of all skilled workers, not only the front-liners. Once there is a shortage of skilled workers on cross-border construction projects, there is a higher possibility of an error occurring on a project due to a lack of regular quality inspections and auditing of construction works, especially when it involves travel across borders. The pandemic mitigation measures may restrict skilled workers or experts from travelling to different countries/economies/borders to audit and verify the quality of construction services and works executed. The use of Spearman's correlation test revealed a relatively fair positive correlation among the critical challenges, except between "legal issues due to a breach of contract terms and conditions (C4)" and "halting of operations and site closure (C8)" ($\rho=-0.009$, $p>0.05$); which showed a negative correlation but insignificant. The highest significant positive correlation exists between "working with masks difficulties (C5)" and "heavy workloads and shortage of skilled construction workers (C3)" ($\rho=0.702$, $p<0.05$), depicting experts are not convenient with working with nose/face masks on as they are faced with breathing issues, especially during auditing and inspection of the quality of works executed or services. Such inconvenience may cause worker absence, and gradually heavy workloads may set in, which may cause stress to the remaining workers (Oo et al., 2021; Oey and Lim, 2021), probably leading to human errors affecting the quality of projects. Management may control this by providing a safe environment to encourage and protect workers throughout the QA process in construction.

Based on the sentiment analysis, the study makes a proposition that the sentiments of the challenges imposed by COVID-19 on the QA of Cb-CLSC have not been entirely negative but have also positioned the construction industry in terms of the adoption of digital technology and innovative management strategies. The challenges have been largely negative, as obvious, but there are also positive sides, as well as the neutral side. For instance, "shortage of raw construction material" has been the challenge with the highest level of sentiment (62.70%). This can be attributed to heavy disruption to the construction supply chain and the auditing of such material to ensure quality (Rankohi et al., 2022; Jeon et al., 2022). However, there have been a neutral sentiment (22.50%) and positive sentiment (14.80%), which can be related to the experts adopting innovative management strategies enabled by digital technologies to ensure adequate QA of Cb-CLSC (Elabd et al., 2020; Lu et al., 2022). This can be confirmed by the fairly distributed sentiment scores >1.50 depicting the sentiment not to be only negative when compared to the model adopted: 1=Negative; 2=Neutral; 3=Positive. Using the Mann-Whitney U test, this sentiment level attained depicts no significant differences between the sentiments from the two groups of experts (academia and industry). Overall, the sentiments on each challenge portray positivity and neutrality that empowers the industry, especially in the field of QA. This denotes that the pandemic comes with opportunities, and the industry may harness these to position the QA of Cb-CLSC to be adequate for the post-pandemic era and endure the risks of future pandemics.

6. Conclusion

From this study, the QA of Cb-CLSC has been impacted by the COVID-19 pandemic imposing critical challenges, with the top five being "shortage of raw construction material", "changes in work practices", "halting of operations and site closure", "heavy workloads and shortage of construction workers", and "design changes". Apart from the negative sentiments, each of the critical challenges also portrayed positivity and neutrality that empowers the industry, denoting that the pandemic comes with opportunities, and the industry can harness these to position the QA of Cb-CLSC to be adequate for the post-pandemic era and endure the risks of future pandemics.

Despite the findings, the study has limitations that need to be acknowledged during the result interpretation and generalisation. The study's outcome relied on 25 economies/countries, which is relatively less than the number of economies across the globe. Hence, future studies can research specific economies not involved in this study to identify some critical challenges and explore the opportunities believed to be created by the COVID-19 pandemic toward positioning the QA of Cb-CLSC to be adequate amid future pandemics. This may also reveal more insights. However, the relevance of the study's results remains due to the rigorous analysis conducted.

Notwithstanding the limitations, the study contributes theoretically to the literature on QA and Cb-CLSC by identifying the critical challenges of QA of Cb-CLSC amid the COVID-19 pandemic. It also contributes to the lessons learned from the pandemic in the construction industry. This knowledge could direct researchers toward developing a resilience framework to position the QA to be adequate for the post-pandemic era and endure the risks of future pandemics. Practically, this study creates awareness of the critical challenges of QA of Cb-CLSC amid the pandemic to the QA teams and policymakers in construction. This could help industry practitioners and researchers understand the impacts of the pandemic and develop innovative management strategies to position the QA of Cb-CLSC to be adequate for the post-pandemic era and endure the risks of future pandemics.

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