Appendix A: Potential resultant impacts of the COVID-19 on QA of Cb-CLSC (Source: Authors own work)

Code	Proposed resultant impacts	Description	Source
M1	Extra cost incurred for QA processes	Extra cost, such as quarantine, has been incurred for conducting QA, especially when it involves experts travelling across borders/countries/economies to audit the quality of works executed and services. This becomes a burden and impacts the overall project cost when QA teams would have to travel offshore, considering the cost of quarantine.	Elnagger and Elhegazy (2022), Al-Mhdawi et al. (2022a), Leontie et al. (2022), Ling et al. (2022), Briggs et al. (2022)
M2	Delay in QA processes	Delay in the QA process has become an issue due to the documentation and quarantines before and during travelling. When this happens, it sets to delay all other activities, especially when they are dependent on the result of quality auditing or inspection before continuation. As such, it is vital to communicate delays caused by the travelling and quarantine effectively on time among required stakeholders during work services and execution.	Al-Mhdawi et al. (2022a), Leontie et al. (2022), Ling et al. (2022), Olatunde et al. (2022); Aigbavboa et al. (2022), Dobrucali et al. (2022); Rankohi et al. (2022), Oey and Lim (2021), Olatunde et al. (2022), Rehman et al. (2022), Agyekum et al. (2022
M3	Disrupted logistics and supply chain	Disrupted logistics and supply chain is one of the commonest impacts of COVID-19 in the construction industry. This issue is severe in cross-border construction projects where it affects the material supply and experts' movement, which is noted to be restricted by border arrangements. For instance, quality auditors, inspectors, and others find it difficult to inspect projects in other countries, impacting the adequacy of QA.	Jeon et al. (2022), Al-Mhdawi et al. (2022b), King et al. (2022), Rehman et al. (2022), Ogunnusi et al. (2021), Husien et al. (2021)
M4	Labour shortage	The number of skilled workers on-site to execute projects has been influenced negatively by the pandemic due to the fear of getting infected by the virus. The volume of work to be executed for a project has been impacted, which also affects the quality of the project being satisfied by the client. Even quality auditors and inspectors fear travelling to execute their services in different countries because it is unethical during the pandemic. As QA requires skilled construction labourers, such as quality inspectors, auditors, etc., to perform their responsibilities, work environments must be safe to encourage labourers to attend to their respective work.	Jeon et al. (2022), Ogunrinde et al. (2022), Niroshana et al. (2022), Stride et al. (2021), Rankohi et al. (2022)
M5	Decrease in work rate.	The work rate has also been impacted, which further affects the results of the QA performed. The work rate of quality auditors and inspectors of cross-border construction projects has not been adequate during COVID-19 because of a lack of adequate information on the project and the executed works and services. As such, organisations need to ensure that adequate information on cross-border projects gets to the QA front-liners for proper evaluation before the continuation of work. This can be achieved by adopting innovative approaches to retrieve information on the project between stakeholders.	Agyekum et al. (2022), Jeon et al. (2022), Ling et al. (2022), King et al. (2022)
M6	Low-quality works	Due to the inadequate QA amid the pandemic, the quality of cross-border projects is not checked properly to meet pre-stated requirements.	Ogunnusi et al. (2021), Aigbavboa et al. (2022), Oladimeji et al. (2022)
M7	Contractual implications and disputes	The COVID-19 pandemic has caused contractual implications due to the inadequate means of checking the quality, where experts are required to travel offshore or across borders to check the quality of services and products in a case of modular construction. Contractual issues and disputes may occur when adequate QA is neglected and allowed workers to carry on project execution. As such, the management of construction organisations needs to be innovative in carrying out the QA activities amid the pandemic, regardless of the difficulties involved.	Olatunde et al. (2022), Ogunnusi et al. (2021), Bsisu (2020), Husien et al. (2021), Umar (2022)
M8	Workforce management and operational control process difficulties	Since QA is a collective effort of employees or workforces in the countries/economies/border involved, there must be effective control and management to ensure effective collaboration and sharing of information among all workers. However, the pandemic has induced difficulties in managing workers and controlling them, making collaboration difficult due to the fear of infection. In some cases, there may be a need for physical inspection and auditing on construction sites, involving the quality auditors and inspectors collaborating with on-site skilled workers. The pandemic has made it difficult. Hence, organisations need to devise innovative means to ensure effective collaboration and communication among workers throughout the QA processes during this pandemic without a physical presence on site.	Zamani et al. (2021), Umar (2022), Oo and Lim (2021), Gan and Koh (2021), Ogunnusi et al. (2021), Rehman et al. (2022)

M9	Reworks	The QA process requires the collective efforts of all experts in the organisation across borders/economies. There, a disruption in any of the efforts of the experts due to the COVID-19 pandemic is likely to cause a rework. This may occur because of ineffective collaboration and communication caused by the pandemic or the low work productivity rate on part of experts. Hence, causing reworks on projects before the final project is completed. This may also be associated with cost increment and waste of resources. Therefore, during the pandemic era, organisations with projects under Cb-CLSC must try as much as possible to avoid reworks by being innovative in carrying out the QA.	Rankohi et al. (2022)
M10	Lack of a safe environment in the workplace	The lack of a safe environment affects the smooth work production toward quality. COVID-19 causes an unsafe work environment for construction workers, and this may affect the quality of projects completed. This is due to the fear created by contracting the virus if the work environment is unsafe. As such, the productivity rate of all workers reduces toward quality, including the construction quality front-liners, such as quality managers, quality engineers, quality auditors, etc. Hence, to ensure an adequate QA process, the management of organisations must ensure that a safe work environment is achieved to minimise fear of COVID-19 and protect the health of workers.	Pamidimukkala et al. (2021)
M11	Work assessment difficulty due to lack of information	Assessment of ongoing works and services is difficult due to the challenges imposed by the pandemic during physical collaboration among experts and the difficulty in travelling across borders/economies to audit and verify quality services and works. This can potentially create errors in the QA process if the volume of ongoing works and services cannot be assessed properly due to a lack of adequate information. As the pandemic has caused significant disruption throughout the QA processes, the management of organisations must devise innovatively to retrieve adequate information on the quality of ongoing services and workers across economies.	-
Keywords used for the literature search		"Impact of COVID-19", "effect of COVID-19", "Construction activities", "Influence of COVID-19", "Built environment", "building industry", "quality assurance", and "quality management activities.	

Appendix B: Detailed reference to Table 1 (Source: Authors own work)

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Appendix C: Informed Consent Form

Dear Sir/Madam,

Quality Assurance of Cross-border Construction Logistics and Supply Chain in the Covid-19 Pandemic Era

You are invited to participate in an ongoing study that forms part of a PhD research by XXXXXXXXXXXX in the Department of XXXXXX, the University of XXXXXXXXX.

I hope to collect data based on your knowledge and experience regarding the implications of COVID-19 on the quality assurance of construction projects. The survey/interview will only take you about 15-20 minutes to complete. I would like to stress that all information collected will remain strictly confidential. Individual details will not be disclosed or identifiable from this survey.

It is important for you to consider if you fall in the following criteria before responding to the questionnaire:

1. You have extensive experience and were theoretically versed in the construction QA processes;
2. You have sufficient direct hands-on experience in construction QA; and
3. You have been involved in at least QA processes in their organization.

If you have any questions about the research, please feel free to contact Mr. XXXXXXXXXXXXX. If you have questions about your rights as a research participant, please contact the Human Research Ethics Committee (HREC), XXXX.

HREC Reference Number: EA210435

I understand the procedures described above and agree to participate in this study (tick the box and proceed to Part II).

☐

Appendix D: Final Questionnaire

A. Demographic Data Section

Kindly respond to the questions by carefully ticking [√] the appropriate box OR typing in the appropriate space for each item based on your valuable knowledge and experience.

1. Please state your country of origin or economy?.....

2. Which sector do you belong?
a. Industry [ ] b. Academia [ ]

3. What is your designation?
a. Academician [ ] b. Quality Auditor [ ] c. Quality Engineer [ ] d. Quality Assurance/Control Manager [ ] e. Authorised person from the government [ ] f. Client representative [ ] g. Other [ ] Please specify…….

4. How long have you been working in the organisation?
a. Less than 5 years [ ] b. 5-10 years [ ] c. 11-20 years [ ] d. 21-30 years [ ] e. More than 30 years

B. Main Questions

Kindly respond by carefully ticking [√] the appropriate section of the tables based on your valuable knowledge and experience.

a. What is your level of agreement on the following resultant impacts of the COVID-19 effects on quality assurance of cross-border construction logistics and supply chain? Please, answer using the Five-point Likert Scales: **1= Strongly disagree; 2=Disagree; 3=Neutral; 4=Agree; 5=Strongly agree.**

b. Kindly rate whether the impacts are **Negative, Neutral, or Positive.**

No.	Resultant impacts	Level of Agreement					Nature of Impact		
		1	2	3	4	5	Negative	Neutral	Positive
1	Extra cost incurred for quality assurance processes.								
2	Delay in quality assurance processes.								
3	Worker absence, labour shortage and decrease in work rate.								
4	Contractual implications and disputes.								
5	Workforce management and operational control process difficulties.								
6	Work assessment difficulties.								
7	Re-organisation of work processes.								
8	Amendments and increase in organisational health and safety protocols.								
9	Changes to how construction sites operate.								
10	Increased use of digital technologies.								
	Other, please state clearly and rank								

(Source: Authors own work)

Appendix E: Interview Questions

A. Demographic Data Section

1. What is your country of origin?
2. What is your designation?
3. What is your qualification?
4. How long have you been working in the firm?

B. Main Question

How has the COVID-19 impacted the way of checking the quality of your project?

Appendix F: Results of the Normality Test and Disparity Test (Source: Authors own work)

Code	Kolmogorov-Smirnov[a]						Mann-Whitney test							
	Level of Agreement			Level of sentiment			Level of agreement				Level of sentiments			
	K S value	df	P-value	K S value	df	P-value	U stat	W	Z-score	P-value	U stat	W	Z	P-value
M1	0.326	52	0.000	0.392	52	0.000	229.000	1049.000	-0.256	0.798	231.500	1057.500	-0.218	0.827
M2	0.261	52	0.000	0.435	52	0.000	183.000	1003.000	-1.292	0.196	200.000	278.000	-1.099	0.272
M3	0.277	52	0.000	0.420	52	0.000	200.500	1020.500	-0.939	0.348	189.000	267.000	-1.357	0.175
M4	0.274	52	0.000	0.342	52	0.000	214.000	292.000	-0.601	0.548	233.500	311.500	-0.167	0.871
M5	0.215	52	0.000	0.338	52	0.000	234.500	312.500	-0.125	0.900	216.000	294.000	0.588	0.557
M6	0.234	52	0.000	0.284	52	0.000	224.000	1044.000	-0.361	0.718	230.500	308.500	-0.229	0.819
M7	0.278	52	0.000	0.248	52	0.000	184.500	1004.500	-1.283	0.199	191.000	269.000	-1.133	0.257
M8	0.249	52	0.000	0.216	52	0.000	198.000	1018.000	-0.960	0.337	226.000	1046.000	-0.323	0.747
M9	0.334	52	0.000	0.258	52	0.000	215.500	190.500	-0.699	0.485	182.500	1002.500	-1.333	0.182
M10	0.345	52	0.000	0.419	52	0.000	221.000	1041.000	-0.471	0.638	166.000	986.000	-1.950	0.051

W=Wilcoxon, df=degree of freedom, P-value significant at ≤0.050 (Asymp. Sig. (2-tailed))

Appendix G: Spearman Correlation Matrix (Source: Authors own work)

Code		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
M1	ρ	1.000									
	P-value										
M2	ρ	0.795**	1.000								
	P-value	0.000									
M3	ρ	0.630**	0.748**	1.000							
	P-value	0.000	0.000								
M4	ρ	0.606**	0.543**	0.452**	1.000						
	P-value	0.000	0.000	0.001							
M5	ρ	0.522**	0.541**	0.474**	0.597**	1.000					
	P-value	0.000	0.000	0.000	0.000						
M6	ρ	0.403**	0.475**	0.399**	0.454**	0.820**	1.000				
	P-value	0.003	0.000	0.003	0.001	0.000					
M7	ρ	0.684**	0.798**	0.583**	0.467**	0.643**	0.651**	1.000			
	P-value	0.000	0.000	0.000	0.000	0.000	0.000				
M8	ρ	0.673**	0.700**	0.841**	0.449**	0.522**	0.452**	0.694**	1.000		
	P-value	0.000	0.000	0.000	0.001	0.000	0.001	0.000			
M9	ρ	0.346*	0.253	0.364**	0.433**	0.390**	0.152	0.177	0.299*	1.000	
	P-value	0.012	0.070	0.008	0.001	0.004	0.283	0.210	0.031		
M10	ρ	0.257	0.183	.322*	0.090	0.093	0.017	0.229	0.397**	0.566**	1.000
	P-value	0.065	0.194	0.020	0.526	0.510	0.906	0.103	0.004	0.000	

ρ = Coefficient value;
**Correlation is significant at the 0.01 level (2-tailed) = P-value;
*Correlation is significant at the 0.05 level (2-tailed) = P-value

Appendix H: Specific Interviewee Responses (Source: Authors own work)

Interviewee	Specific response	Relation to the critical resultant impacts	Area of the impact in QA
A	• *"Engineering materials transport depends on epidemic prevention and control measures in different countries or areas. This will affect the continuity of our testing, increasing the time cost."*	M1, M5, M6	1. Material needed. 2. Work process including inspection, testing, auditing, communication, etc.
B	• *"The project was suspended, so the project quality testing was not carried out. Therefore, the application of information technology in quality testing began to replace the traditional quality testing method."*	M2, M10	Work process including inspection, testing, auditing, communication, etc.
C	• *"The staffs continually take sick leaves, resulting in temporary shortage of human resources or project interruption."* • *"Due to government's COVID-19 lockdown policy, we employees cannot be at work for a long time."* • *Due to the uncertainty of the COVID-19 epidemic, the decision-making costs and risks of interregional projects have increased, and projects in epidemic areas have often fallen into a state of suspension."*	M2, M3, M5	1. Time. 2. Cost. 3. Work process including inspection, testing, auditing, communication, etc.
D	• *"Increase in project cost and timelines"*	M1, M2	1. Cost. 2. Time.
E	• *The pandemic still has some impact on our work. The main thing is the cost. Measures such as personnel rework isolation, procurement of epidemic prevention materials, and strengthening daily monitoring will lead to increased costs. "The centralised start of work after the end of the epidemic may increase the cost of rework."*	M1, M7, M8, M9	1. Cost. 2. Work process including inspection, testing, auditing, communication, etc.
F	• *"The control of traffic and logistics creates an obstacle to the transport of people and equipment. Isolation observations have had an impact on the work of staff."* • *"Restrictions on travel have had a serious impact on the departure of in-country operatives to resume work and carry out their work."*	M5, M6	Work process including inspection, testing, auditing, communication, etc.
G	• *"The current policy of vaccination in China is strict and work is often suspended. Due to government regulations, we have to carry out daily nucleic acid testing, so when there is an epidemic impact, our orders are basically not completed on time."*	M2, M5	Work process including inspection, testing, auditing, communication, etc.
H	• *"The slower pace of production operations has increased project quality monitoring cycles, increased risk of schedule defaults and difficulties in delivering raw materials."*	M2, M4, M5, M7	1. Material needed. 2. Time. 3. Work process including inspection, testing, auditing, communication, etc.
I	• *The current quality testing work is more complicated than the previous testing work, with more related requirements, such as the need to disinfect cross-border prefabricated components."*	M6, M7	Work process including inspection, testing, auditing, communication, etc.
J	• *"We are unable to directly travel between the territory and the territory. If we have to travel, we need to be quarantined according to the policy, which increases the labour cost in the factory."*	M1, M2, M7	1. Cost. 2. Work process including inspection, testing, auditing, communication, etc.
K	• *"The main impact is on quality management personnel, as they are restricted by the government's epidemic prevention and control policies."*	M3, M6	Work process including inspection, testing, auditing, communication, etc.
L	• *"In particular to the off-site fabrication factory/yard in China, there is a critical impact that the quality check to items fabricated in the factory/yard could not be checked because of the lockdown."*	M3	Work process including inspection, testing, auditing, communication, etc.
M	• *"Site works are delayed by the inspector if there is confirmed case in the project team."*	M2	1. Time. 2. Work process including inspection, testing, auditing, communication, etc.