Evaluating the Impact of COVID-19 Mitigation Measures on Quality Assurance of Cross-border Construction Logistics and Supply Chain

Frank Ato Ghansah[a] and Weisheng Lu[b]

[a] Division of Construction, Property and Surveying; School of the Built Environment and Architecture, London South Bank University; London; United Kingdom.

[b] Professor, Real Estate and Construction Department, Faculty of Architecture, The University of Hong Kong, Hong Kong.

Abstract

Purpose: While COVID-19 mitigation measures (CMMs) aided in steady recovery during the pandemic, they also impeded movement across economies/borders, affecting quality assurance (QA) of Cross-border Construction Logistics and Supply Chain (Cb-CLSC). However, prior studies on the pandemic in the construction project industry have not revealed how CMMs have impacted QA. Thus, this study aims to evaluate the impact of the CMMs on the QA of Cb-CLSC.

Methodology: This is achieved by adopting an embedded mixed-method approach involving a desk literature review and engaging 150 experts from different economies across the globe using expert surveys, and results verified via semi-structured expert interviews. Structural equation modelling-based multiple regression analysis (SEM-MRA) was integrated to examine the impact of the CMMs on the QA, along with descriptive and content analysis.

Findings: The study confirmed that CMMs have not only impacted the QA negatively but also influenced the positioning of the QA for the post-pandemic era and probably to survive the risks of future pandemics. Among all the identified CMMs, the top three critical measures include "lockdown (CMM2)", "use of personal protective equipment, such as nose masks, disinfects, etc. (CMM5)", and "electronic/virtual meetings (CMM7)". However, CMM5 possesses the highest contributory power to form CMM in impacting the QA, and this can be regarded as largely positive by strengthening health and safety management systems. Its negative impact lies with the project cost increment and the inconveniences of using nose and face masks.

Practical Implication: This study provides a better understanding to construction practitioners and policy makers on how the pandemic policies, i.e., CMMs, have impacted QA and can aid in formulating planning and operational decisions to adequately position the QA for the post-pandemic era and to endure the risks of future pandemics.

Originality: The study contributes to knowledge in that it provides a better understanding of how the pandemic policies, such as CMMs, have impacted QA and can aid in formulating planning and operational decisions to adequately position the QA for the post-pandemic era and to endure the risks of future pandemics. This area of study has been given limited attention among prior studies during the pandemic.

Keywords: COVID-19 mitigation measures, Construction Quality Management, Cross-border Construction Logistics and Supply Chain, 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 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). This differentiates QA from quality control, though the terms are occasionally used interchangeably. QA is process-oriented and focuses on improving processes and methodologies to develop a quality project by engaging every member of an organisation toward defect avoidance. In contrast, quality control is product-oriented and focuses on improving end products by identifying and fixing defects, involving specific teams that test the products (ReQtest, 2016). The study focuses on the QA as it investigates the systematic process and the procedural activities in ensuring that construction project meets quality requirements. However, quality control may also be an important aspect of QA processes, where individual finished sub-works are examined and tested to verify quality before proceeding to the next sub-works (ASQ, 2015).

QA facilitates the improvements of quality processes and tailors the processes to ensure the client's requirements are met along with statutory and organisational requirements. With QA integrated fully into Cb-CLSC, it regulates the conduct of different processes and prevents side-stepping (Chung, 2002). Suppose any certain process is found deviating or with an error from the established procedure; the untoward event is reviewed by management, and a loophole is plugged in to prevent a recurrence. This depends on effective collaboration and communication with multiple stakeholders across all borders; hence, making QA a complex practice with concerns of being time-consuming; laborious, and prone to numerous human errors/mistakes.

The complexity of performing QA has worsened due to the coronavirus (COVID-19), which was introduced as a pandemic in March 2020 (World Health Organisation [WHO], 2020a). The COVID-19 mitigation measures (CMMs), though they have helped achieve steady recovery (Office for National Statistics [ONS], 2021; Eurostat, 2022), have also impeded the movement between countries/borders/economies during QA; hence, disrupting the construction supply chain. These include social distancing, lockdown, travelling restrictions, and limited workplace capacity (Organization for Economic Co-operation and Development [OECD], 2020; Ghansah and Lu, 2023). The construction activities, such as QA, have been disrupted severely, including the workers' close coordination and interactions, communications, work execution, supply of materials, manufacturing, and human resource availability. This has affected the quality of work and services performed on construction sites toward the overall project quality. For instance, relating the quality of construction products to construction output, 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 project industry from perspectives. For instance, Ogunnusi et al. (2020) investigated the impact of the general construction industry without considering the specific fields in the industry and how they have been uniquely impacted. Pamidimukkala et al. (2021) explored the unique impacts of the pandemic on the health and safety of construction workforces, whiles Leontie et al. (2022) and Elrefaey et al. (2022) investigated the impacts on the use and adoption of digital technologies in the construction industry. Other varied studies have been conducted in areas including health and safety management (Kum et al., 2023; Sadeh et al., 2023), construction performance (Gumusburun Ayalp and Civici, 2023), and construction supply chain management (Sutterby et al., 2023). With QA being the focus of this study, which has received limited attention, Ghansah et al. (2023) explored the critical areas of QA and examined their sentiments amid the pandemic, considering Cb-CLSC. Nevertheless, it is still unclear how the CMMs have affected the QA. Meanwhile, understanding these complexities could assist the construction project sector to be more innovative in adapting to the challenges created by the pandemic, and survive future pandemic effects.

This study, therefore, aims to evaluate the impact of the CMMs on the QA of Cb-CLSC. This is achieved by (1) identifying and examining the level of sentiments of the CMMs to understand their impacts on the QA and (2) quantifying the collective impacts of the CMMs on the QA. This is accomplished by engaging experts across the world from different economies via an embedded mixed-method approach using expert online surveys, and results verified via semi-structured interviews. The findings of this study could create awareness and understanding among the specific practitioners and policymakers on how the established COVID-19 policies have affected construction activities, especially Cb-CLSC, and lessons could be taken for future endeavours. This study also contributes to knowledge by assessing the impact of the CMMs on QA and their associated sentiments. This may guide researchers to further QA research in the construction project industry. The structure of this paper is as follows: introduction, literature review, research methods, analysis and findings, discussion of findings, and conclusion.

2 Literature Review

2.1 QA of Cb-CLSC

Cb-CLSC is complex, including important interrelated construction activities such as duties, border crossing, track record, and proper transportation (Pilatowska, 2021). This is significant for promoting international trade and the construction market. For this study, the definition of Cb-CLSC by Mawhinney (2008) is adopted due to its conciseness and understanding, and the definition is "where one company, resident in one economy, performs construction works in another economy." Construction activities are carried out by different subjects from different countries/borders, where the subject may refer to legal persons or multi-national firms.

QA, according to the project management body of knowledge [PMBOK] (2017), is part of a project quality system of an organisation, and it ensures that project deliverables meet planned quality standards. The ISO (1994) defined QA as a set of activities to ensure that a project meets all quality requirements, including client requirements, statutory/regulatory requirements, and organisation requirements. ISO 9001:2015 explicitly terms QA as proactive process-oriented, and it is related to the ISO 9000 family of standards, which specifies the quality system requirements for organisations with different scopes of operation. QA maintains consistent quality in construction by avoiding mistakes in the first instance. Such preventive measures must be ensured among the construction workers, from the top management to the labourers in charge, by minimising the risk of managerial and communication problems, which may affect project quality. For this study, it is important to also acknowledge the significant difference between QA and quality control, mostly used in conjunction in literature. As QA focuses on improving processes and methodologies (proactive measures) to develop a quality project by involving every member of an organisation involved in developing a product, quality control focuses on improving end-products by identifying defects (product-oriented) (reactive measures) by engaging specific teams that test the products (ReQtest, 2016; Hamilton, 2023). The study focuses on the QA as it investigates the systematic process and the procedural activities in ensuring that construction project meets quality requirements. However, quality control may also be a significant aspect of QA processes, where individual finished sub-works are examined and tested to verify quality before proceeding to the next sub-works (ASQ, 2015). Consequently, this study adopts ISO's (1994) definition of QA due to the international acceptance of ISO, and this study's focus is limited to the Cb-CLSC.

Conducting QA depends on an organisation's quality management system, which embraces organisational resources, structure, and procedures (Khan et al., 2008). Integrating QA into Cb-CLSC regulates operations and prevents side-stepping or deviation from quality requirements. QA has been the responsibility of the contractor, consultant, designer, and government-authorised agencies. Hence, a concerted effort is central to achieving an adequate QA by ensuring everyone in the organisation knows what they are expected to do and what their colleagues are doing. 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 concept, specifically between the Guangdong Province of Mainland China and Hong Kong SAR, where authorised and client representatives are dispatched offshore to verify and accept the quality of modular components (Lu et al., 2022).

2.2 COVID-19 Outbreak and Construction Project Industry

COVID-19 was declared a pandemic in March 2020 (WHO, 2020b) and has gained a rapid global transmission rate, recording nearly 600,000,000 confirmed cases and 6,436,519 deaths (WHO, 2022). This has been noticed with countries recording their share of the transmission, see Figure 1, which is alarming, especially to the Cb-CLSC, where one needs to travel offshore to inspect the quality of construction works. Consequently, visionary stakeholders, including the government, understood the dynamics of COVID-19 and recommended mitigation strategies and best practices, including vaccination programs, physical/social distancing, site reconfiguration, maintaining good environmental and indoor ventilation, wearing nose masks, etc.

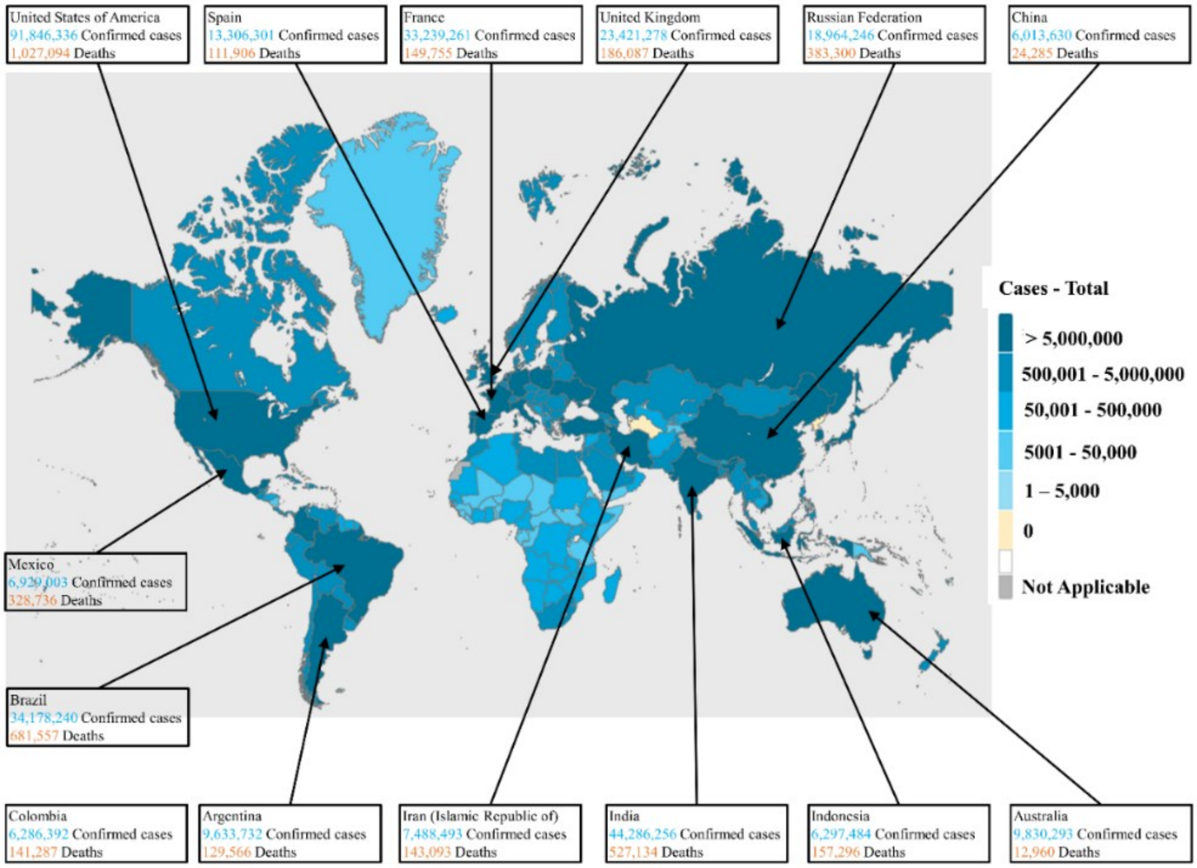

Figure 1: COVID-19 Cases across Countries (WHO, 2020b)

COVID-19 has considerably impacted the construction project industry, putting construction workers at a higher risk of severe infections than non-construction workers (Ghansah and Lu, 2023). Baker et al. (2020) reported that in April 2020, 8.3% of the 5.9 million construction workers during the pandemic were exposed once a month. Subsequently, this led to delays and suspension, cancellation of projects, creation of new risks, etc. This has raised a more significant consent on QA of Cb-CLSC, which engages contractors and other professionals between countries/borders where one performs services in the different countries. The CMMs, as much as they minimise the spread of the pandemic, have also affected construction activities. A desk literature review of articles from journal papers, conference papers, and white papers denoted a set of CMMs explained in Appendix A.

2.3 Knowledge Gap

Prior studies have investigated the impact of the pandemic on the construction project sector from different perspectives. For instance, Ogunnusi et al. (2020) investigated the impact of the general construction industry without considering the specificity of the fields, which may have been uniquely impacted. Considering the pandemic's impacts on specific fields, Pamidimukkala et al. (2021) explored the unique impacts on the health and safety of construction workforces, Leontie et al. (2022) and Elrefaey et al. (2022) also investigated the impacts on the use and adoption of digital technologies in the construction industry. Other varied studies have been conducted in areas including health and safety management (Kum et al., 2023; Sadeh et al., 2023), construction performance (Gumusburun Ayalp and Civici, 2023), and construction supply chain management (Sutterby et al., 2023). With QA, which is the focus of this study due to limited or no study, Ghansah et al. (2023) explored the critical areas of QA and examined their sentiments amid the pandemic, considering Cb-CLSC. However, how the CMMs have affected the QA, especially the Cb-CLSC, is still unclear.

This study, therefore, aims to evaluate the impact of the CMMs on the QA of Cb-CLSC by engaging experts across different economies via an embedded mixed method approach. Understanding these complexities might help the construction project industry to be more creative and proactive in managing the pandemic policies and responding to the associated challenges toward attaining adequate QA systems for the post-pandemic era and surviving the risks of future pandemics (Ghansah and Lu, 2024; Ghansah et al., 2024). Based on the gap, this study makes a hypothesis (**H_{C1}**) that

***H_{C1}**: COVID-19 mitigation measures have a significant positive impact on the QA of Cb-CLSC.*

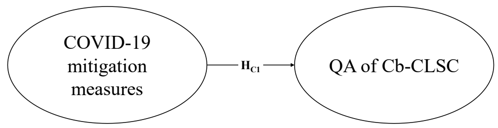

Figure 2: Hypothetical Framework (Source: Authors own work)

3 Research Methods

This study adopted the embedded mixed-method approach via a pragmatic worldview. With this approach, the superiority exists by collecting qualitative and quantitative data and analysing with the traditional quantitative research design (Creswell and Clark, 2017). This implies using qualitative data to complement and validate the results of the quantitative data. However, its weakness lies in being biased because it gives a preconceived mind on what the researcher expects from the qualitative data. Hence, the researcher may miss discoveries from the qualitative data. This approach has been adopted for construction management and engineering research in specific fields, such as housing needs evaluation (Ijasan and Ahmed, 2016), etc. Overall, the embedded mixed-method approach for this study follows two main steps, as discussed below.

3.1 Identification of the CMMs

A desk literature review was used, which entails a thorough examination of the body of knowledge on a certain research topic that is currently available, including books, journals, conference articles, and other scholarly publications (Muheeb, 2021). Instead of doing hands-on experiments, this method is conducted at a desk through study (Designbuildings, 2021). Finding pertinent data sources and evaluating data quality are the primary goals. The desk literature review, in contrast to other literature techniques, is primarily concerned with rapidly locating pertinent sources and evaluating the body of existing literature to pinpoint important details (Muheeb, 2021; Designbuildings, 2021). This approach is frequently the first phase in the research process (Designbuildings, 2021).

For this study, the desk literature review was conducted to identify the CMMs, as discussed in Appendix A. Keywords were entered to find relevant related literature in Google, google scholar, Scopus, and Web of Science databases. These include “COVID-19 mitigation measures”, “COVID-19 policy measures”, and “Pandemic policy measures. Twenty-three academic documents were identified, including journal papers, conference papers, and white papers consisting authentic and reliable web pages of organisations, such as the Centre for Disease Control and Prevention (CDC), etc. The study stuck to the saturation point in the literature proposed by Saunders et al. (2018) to stop when measures reappear. Subsequently, six CMMs were proposed to be evaluated to understand their impacts on the QA of Cb-CLSC based on the experts’ views.

3.2 Data Collection

An initial questionnaire on the six CMMs was prepared, and the intention was to determine the impact of the CMMs on QA by considering the sentiments from the experts’ viewpoints (academia and industry). The questionnaire allowed empirical data collection different economies across the world, guaranteeing experts’ anonymity and data confidentiality. The Likert scale was adopted due to the introduction of minimal response bias. As a result, the type of Likert scale adopted includes a level of sentiment (1=negative, 2=neutral, 3=positive) and level of impact (1= Very low impact; 2=Low Impact; 3=Moderate; 4=High impact; 5=Very high impact).

The study conducted a pilot study to check the comprehensiveness and relevance of the CMMs by engaging valuable responses from five experts (three academicians [one from the UK, one from Australia and one from Hong Kong SAR] and two quality inspectors [one from Hong Kong SAR and the other from Mainland China]). The valuable comments helped modify the six CMMs to seven by introducing electronic/virtual meetings (See Table 1), informing the final questionnaire (Appendix C). Alongside, QA activities were also identified to help quantify the impacts of CMMs on the QA (See Appendix C). The interview questions were also piloted to have well-refined questions to interest experts' participation (Appendix D).

Table 1: CMMs After the Piloting (Source: Authors own work)

Code	CMMs	Source
CMM1	Social distancing	1,2,3,4,5
CMM2	Lockdown	6,7,8,9
CMM3	Travelling restrictions	10,11,19
CMM4	Workplace capacity limit	12, 22,23
CMM5	Personal Protective Equipment (PPE)	13,14, 21
CMM6	Quarantine days	4,15,20
CMM7	Electronic/virtual meetings	16,17,18

For detailed references, see Appendix E.

The study population comprises construction QA experts from academia and industry possessing relevant experience from different economies across the globe. QA is a collective effort in a construction firm on a project. Hence, project managers and construction managers were also engaged as experts in this study, as defined by Cabaniss (2022). Also, non-probability sampling techniques, such as purposive and snowball sampling, were adopted by targeting experts with knowledge and experience in construction QA. This helped direct the researcher to potential experts.

The study considered experts if (1) they possess extensive experience and are theoretically proficient in the construction QA activities, (2) they possess direct hands-on experience in construction QA, and (3) they have at least been engaged in the QA process in the construction industry. The study identified academic experts from highly recognised peer-reviewed journals with high contributions to the field of construction QA, while the industry practitioners comprised experts from construction companies. Overall, the experts were also searched from professional associations via LinkedIn and direct company websites, giving access to retrieve contact email addresses of industry practitioners.

An online survey was adopted to distribute the questionnaires using *"Qualtrics XM"* through personalised emails to allow easy responses, LinkedIn, CNBR, WeChat, and WhatsApp messenger. This was conducted along with the interview session via online platforms, such as Zoom and WeChat. The duration of the data collection continued for five to six months. The experts were prompted with several reminders to remind the experts to respond to the survey and attend an interview session if available.

Due to the snowball sampling technique adopted for this study, the number of questionnaires distributed was not determined. However, an approximate value of 200 online questionnaires could be estimated for the distribution. This is based on the targeted participants and assumption that they may be forwarding to their colleagues. This was verified after contacting few on their ability to share, and the response was positive. Finally, 150 responses were collected from the experts. A limitation of this approach is the accurate estimation of the response rate, as the respondents forwarded the survey to potential experts. However, it is suggested that a minimum sample size of 30 is recommended as appropriate for analysis (Ott and Longnecker, 2015). Hence, 150 is relatively high for analysis in this study. Correspondingly, eight interviews were conducted to derive insight to complement the survey findings, meeting the minimum requirements for a qualitative study: 5-50 participants (Dworkin, 2012).

4 Data Analyses and Results

To commence the data analysis, the collected dataset was initially cleansed to remove uncompleted responses. The Statistical Package for the Social Sciences (IBM–SPSS), version 27, was then adopted to aid the data analysis.

4.1 Experts' Demographic Profile

Figure 3 details the profile of the experts engaged in the survey, whereas Table 2 presents the profile of the interviewees. Overall, the experts highly constituted those from Ghana, Hong Kong SAR, and Mainland China with 24.7%, 19.3%, and 15.3% respectively. The response rate of experts from the academia was 23.09%, a good survey response reflecting the consent of the academia (Cleave, 2020), while the industry was 76.92%, across economies with specialities, such as academics, quality auditing, and quality engineering. It also engaged authorised persons from the governments, client representatives, and others. The "others" included other team members deemed essential in the QA process, i.e., project managers, construction managers, and site supervisors. Most experts had years of work experience from 1–10 years either by research or industry experience, and few had work experience from 11–20 years. With the interviewees, experts were noted to be highly qualified with academic certificates and work experience from two to seven years.

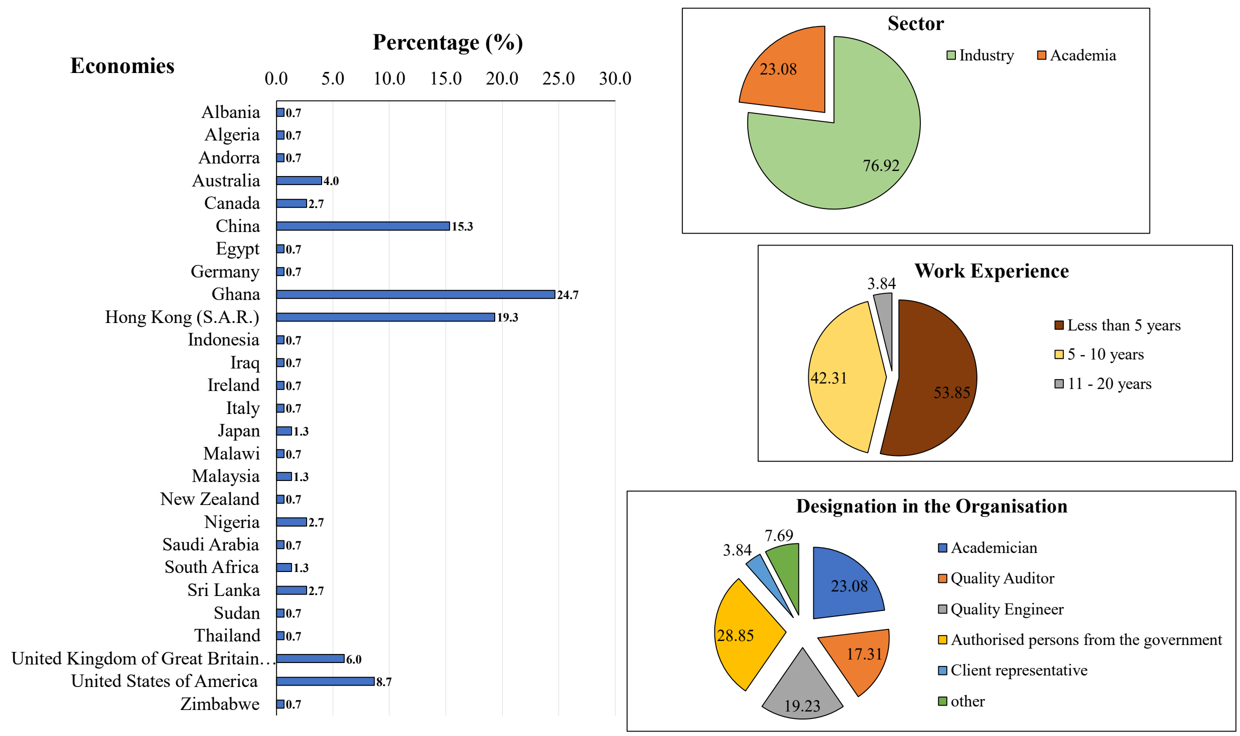

Figure 3: Experts' Profile (Source: Authors own work)

Table 2: Profile of Interviewees (Source: Authors own work)

Interviewee	Designation	Qualification	Years of Experience
C	Quality Engineer	BSc	2
E	Quality manager	MSc	4
F	Quality inspection officer	MSc	3
G	Onsite quality inspection officer	BSc	2
I	Director of Quality Management System Department	MSc	4
J	Quality officer (in charge of logistics)	BSc	2
K	Supply chain manager	MSc	6
L	Quality Engineer	BSc	7

4.2 Normality Test, Descriptive Analysis, and Sentiment Analysis of the CMMs

The dataset showed excellent internal consistency using Cronbach's Alpha (CA) value recorded as the level of sentiment (0.893) and level of impact (0.630) (Pallant, 2001). Hence, further analysis is conducted to evaluate the dataset.

The Kolmogorov-Smirnov test of normality showed the related dataset not to be normally distributed (see Appendix F) regarding the impact of the CMMs and the sentiment level. The central tendency of the experts' sentiments on the CMMS and the impact level was relatively good, including the values for the standard deviation. The sentiment score was based on the central tendency of the experts' responses on the level of sentiment on CMMs. Finally, the level of criticality on the level of sentiment and the impacts were deemed more critical, as the normalised scores for the CMMs were $\geqslant 0.500$ (Adabre et al., 2020). For the results of the normality test, descriptive analysis, and sentiment analysis results, see Appendix G, whilst the mean confidence level at 95% on the dataset is shown in Appendix H[S2].

4.3 Disparity Test

The Mann-Whitney U test was adopted due to the non-parametric nature of the dataset to assess the degree of association of the experts' rankings of the level of sentiments/impacts from the perspective of academia and industry practitioners. With this test, the null hypothesis, H_0, is that

"there is no significant disparity vis-à-vis the level of sentiments/impacts of the CMMs on the QA practices of Cb-CLSC among the two groups (academia and industry)."

The H_0 can therefore be rejected if the P-value is less than or equal to the significant level of 0.05. For the results of the disparity test between academia and the industry, see Appendix F.

4.4 Content Analysis

Finally, the expert interview data were evaluated further to complement and validate the quantitative data findings. This helps to provide a solid backing to understanding how the CMMs have impacted the QA, hence, supporting the sentiment analysis. This validates the assertion that the CMMs have severely impacted the QA and relates to the policies that restrict experts from performing their QA tasks. For the specific responses from the interviewees concerning the impacts of the CMMs on the QA, which were noted to be largely negative, see Appendix I.

4.5 Structural Equation Modelling-Based Multiple Regression Analysis (SEM-MRA)

For this study, the collective impact of CMMs seems to be complicated as the impacts on the QA are measured by the positive-neutral-negative model (see Appendix C) by Ghansah et al. (2023). This seems challenging for the traditional multiple regression approach. Hence, the SEM-MRA is adopted to examine the impact of the CMMs on the QA. It is done using partial least squares-SEM to perform multiple regression through the AMOS software, as illustrated in Figure 4, by following the five logical steps: specification, identification, parameter estimation, model evaluation, and model modification (Kline, 2015). This analyses the causal relationships between several variables; hence, effective and efficient in conducting direct and indirect analysis of one or more independent variables on one or more dependent variables, compared to the traditional multiple regression (Bentler and Wu, 2005), showing the disparity between the error variance and true variance. PLS-SEM was adopted because the study's sample size meets the thumb rule proposed by Barclay et al. (1995): "the minimum sample size should be greater than ten times the largest number of inner model path directed at a particular construct in the inner model".

The reliability is checked by adopting composite reliability (CR) scores and Cronbach's Alpha (CA), which were set at a cut-off point: CR of 0.700 and CA of 0.600, especially when dealing with reflective measurement models of PLS-SEM. For formative measurement models, this study agrees with Rossiter (2002, p. 388) by claiming that "for a formed attribute, there is no […] no question of unreliability". As such, researchers skip the reliability issue when discussing formative measure development and regard it as not meaningful (Bagozzi, 1994).

For this study, the validity assessment of the reflective model is dismissed following Rossiter (2002, p.315) when stated that "all that is needed is a set of distinct components as decided by the expert judgement". Also, the variables in the formative measurement model are approved CMMs by experts and other international health organisations. For the reflective measurement model, convergent validity must be tested as satisfactory for this study. The factor loadings, which show the relationship between the measurement items and the corresponding construct, need at least 0.500. Also, the average variance extracted (AVE) must be greater than 0.500, representing the mean value of the squared loadings of a set of measurement items. This is performed for reflective models (Hair et al., 2014). For discriminant validity, constructs are tested to see if they truly measure what they are intended to measure originally or how a construct can be different from others. This explains that the construct's variance with its measurement item should be higher than what it shares with any other construct. Considering the initial model (Figure 4), there are no cross-loadings showing how a construct shares a measured item with other constructs. Hence, the discriminant validity test is not applicable.

The path coefficient is then determined to understand the relationship between the CMMs and the QA toward the collective impact of the CMMs. The higher the coefficient, the stronger the impact. Bootstrapping is further performed to attain a stable result, as Hair et al. (2014) recommended, suggesting a significant path at $P \leq 0.050$ at a 95% confidence level. Variance inflation factor (VIF) is adopted to determine the multicollinearity issues by following the thumb rule: <10 represents the absence of multicollinearity issues (Salmeron Gomez et al., 2020). Finally, the coefficient of determination (R^2) is estimated to predict the impact of CMMs on the QA. The result denoted the proposed hypothesis ($\mathbf{H_{C1}}$) to be retained, as confirmed with a significant strong positive correlation of 0.944 at P-value<0.050, explaining 89.1% of the variance concerning the CMMs influencing QA. Figure 5 and Table 3 show the results direct effect relationship after running the test with the data, while Appendix J and K show additional results on the direct and indirect effect relationship of the CMMs on the QA.

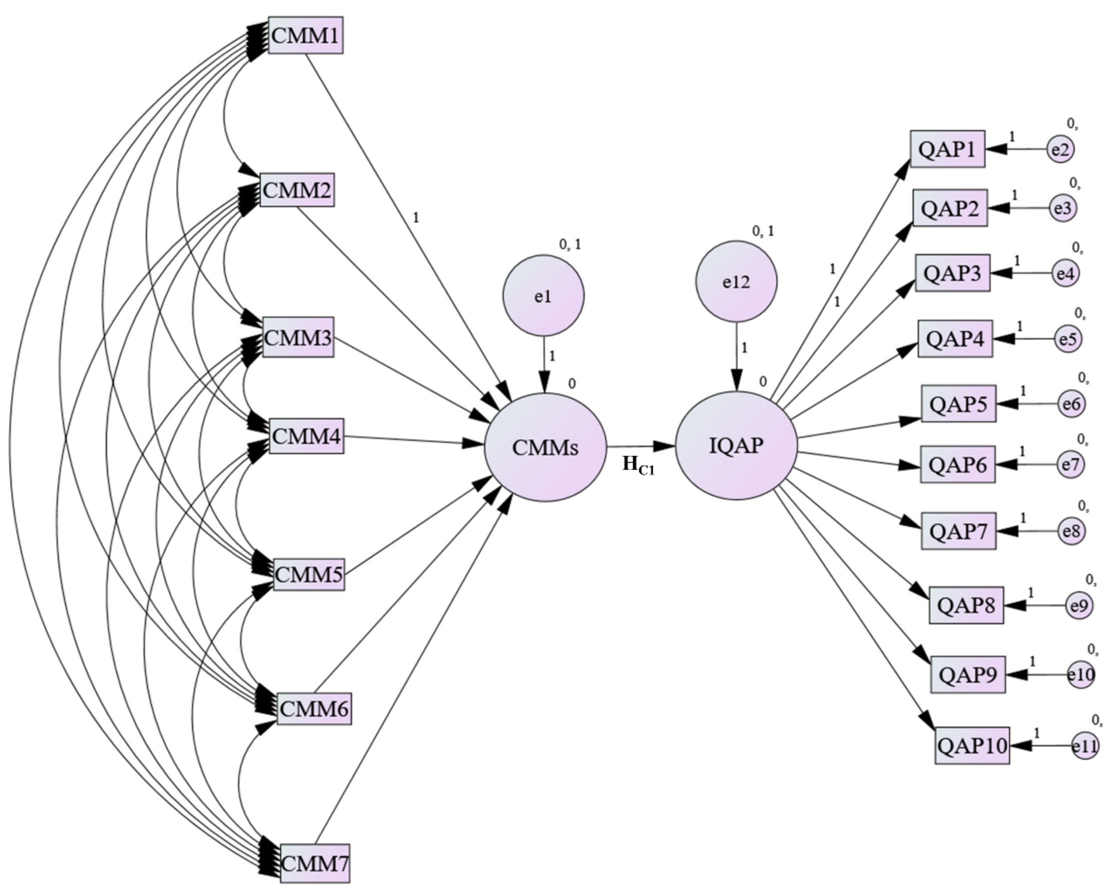

Figure 4: Initial Model (IQAP = Impacts on QA) (For detailed references on QAP1 to QAP10, see Appendix B, and for the mean confidence level at 95%, see Appendix H[S1]) (Source: Authors own work)

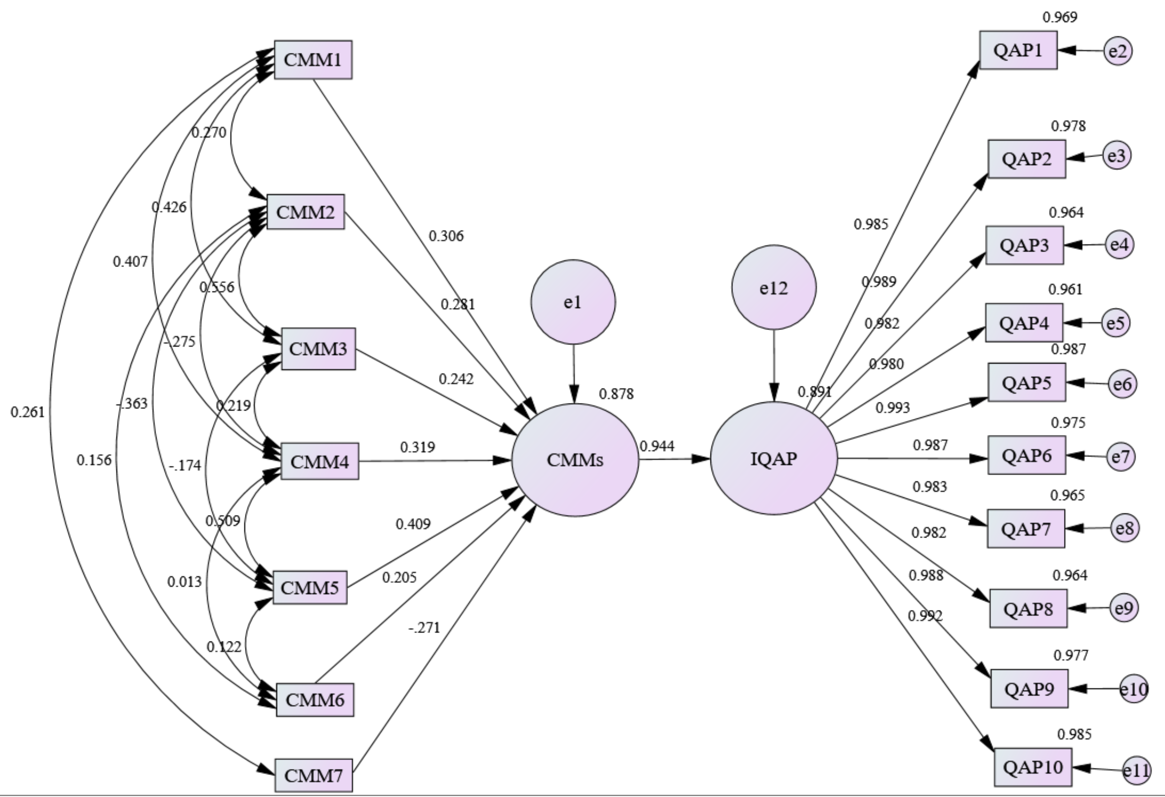

Figure 5: Final Model Showing the Impacts of CMMs on QA Using the Standardised Regression Weights (Simulation Information: 12 iterations, Chi-square = 624.7, df = 122) (Source: Authors own work)

Table 3: Standardised Direct Effect of CMMs on QA (Source: Authors own work)

Relationship				**CR**	**CA**	**AVE**	**P-value**	**VIF**	**R^2**
A. Measurement Model									
Formative measurement model									
CMM1	→	Direct	CMM	-	0.630	-	0.006*	-	0.878
CMM2	→		CMM				0.006*	-	
CMM3	→		CMM				0.024*	-	
CMM4	→		CMM				0.018*	-	
CMM5	→		CMM				0.018*	-	
CMM6	→		CMM				0.018*	-	
CMM7	→		CMM				0.039*	-	
Reflective measurement model									
IQAP	→	Direct	QAP1	0.997	0.831	0.972	0.061	-	0.969
IQAP	→		QAP2				0.038*	-	0.978
IQAP	→		QAP3				0.167	-	0.964
IQAP	→		QAP4				0.201	-	0.961
IQAP	→		QAP5				0.030*	-	0.987
IQAP	→		QAP6				0.287	-	0.975
IQAP	→		QAP7				0.201	-	0.965
IQAP	→		QAP8				0.113	-	0.964
IQAP	→		QAP9				0.075	-	0.977
IQAP	→		QAP10				0.093	-	0.985
B. Structural Model									

CMM	→	Direct	IQAP	-	-	-	0.018*	9.109	0.891

*Significant at P≤0.050, P-Value = Two-tailed significance level at 95% confidence level after bootstrapping; CR=Composite reliability; CA=Cronbach's Alpha; AVE= Average Variance Extracted; VIF=Variance inflation factor

5 Discussion

5.1 Sentiments of the CMMs on the QA of Cb-CLSC

This study reveals that, while CMMs impede QA activities, there are also positive aspects that need to be harnessed appropriately. The sentiment analysis revealed the CMMs to mostly have a neutral-to-positive sentiment on the QA, i.e., most of the CMMs were found to attain a sentiment score ranging between 2.000 and 3.000. The highest sentiment score was noted to be assigned to "use of personal protective equipment, such as nose masks, disinfectant, etc. (CMM5) (2.58)", followed by "electronic/virtual meetings (CMM7) (2.42)" and "workplace capacity (CMM4) (2.37)". However, the sentiments on these CMMs were also distributed percentage-wise on whether negative, neutral, or positive. Sentiments on the CMM5 were noted to be the most critical, as the level of criticality was recorded as CMM5 (0.790), followed by CMM7 (0.710) and CMM4 (0.685). Aside from the first three CMMs mentioned, the remaining CMMs were also noted to have a high level of criticality due to their positive impact on the QA, except "lockdown (CMM2)" and "travelling restrictions (CMM3)". Nonetheless, it is important to acknowledge the fact that CMM2 and CMM3 may have significant impacts on QA as have been reported to affect construction activities, such as physical or onsite work services, travelling in-between regions or borders, halting of work services, delays of services, and so on (Ling et al., 2022). Using the Mann-Whitney test depicted no significant difference and disparity between the industry and academia regarding the sentiments on how the CMMs have impacted the QA.

Regarding CMM5, which was identified with the highest sentiment score, the study revealed a sentiment comprising 9.60% negativity, 23.10% neutrality, and 67.30% positivity. The study revealed the CMM5 to be largely positive. The negative impact of the CMM5 on QA can be related to the inconveniences created for experts when executing services using nose and face masks, leading to breathing issues and other health problems (Rosner et al., 2020). Such issues may lead to the absence of experts from work or reduce work efficiencies, affecting the quality of the entire project during delivery. Another adverse impact can be related to the increase in project cost, which can be related to the extra cost incurred for providing additional personal protective equipment to minimise the spread of the pandemic, including nose masks, face masks, hand sanitisers, etc. This may also influence the quality of the project in terms of the cost increment, which may not be satisfying to the key stakeholders, comprising the client, etc. This confirms the assertion made by interview E when stated that

*"Measures such as personnel rework isolation, **procurement of epidemic prevention materials**, and strengthening daily monitoring and monitoring will lead to increased costs."*

- *(Interviewee E, Quality Manager)*

The neutral effect of the pandemic shows how positivity could be used against the negative impact. Hence, the study considers these in unison as opportunities, though the data analysis and findings showed distinct data distribution for each. The pandemic has impacted activities throughout the QA process by creating opportunities for organisations and experts to strengthen health and safety management (Pamidimukkala et al., 2021; Kum et al. 2023). The opportunity can be geared toward creating a safe environment for experts to execute works and ensure compliance in producing quality works and services throughout the QA process of cross-border construction. Utilising the opportunities, health and safety policies and regulations could be established and communicated appropriately among the experts or workforce to increase the organisations' dynamic capabilities and resilience throughout the QA process during the pandemic.

Following CMM5 is the CMM7, which depicts sentiment consisting of 5.76% positivity, 46.15% neutrality, and 48.07% positivity. CMM7 is largely depicted to be positive toward the QA. The negative impact of CMM7 on the QA practices could be attributed to the additional cost incurred for setting up electronic/virtual meetings using digital technologies and the skills to ensure the efficient operability of the adopted technologies. Organisations will also need to include an extra cost to cater to the expenses regarding adopting digital technologies for virtual meetings and orientation on using such technologies (Elrefaey et al., 2022). However, CMM7 is associated with opportunities if handled appropriately with security. CMM7 has been the best practice for communicating among experts, especially in the case of region-to-region projects. With cross-border projects, QA may require experts to travel to audit and verify the quality of work and services in a different region and attend meetings. This ensures compliance with the pre-stated quality requirements of the cross-border projects. However, the pandemic imposes constraints on such movement, creating an opportunity for an organisation to be innovative by adopting digital technologies to ensure the continuity of QA activities. Real-time communication and collaboration can be achieved among the experts during the virtual meeting throughout the QA process by adopting digital technologies, such as building information modelling technology and 5G networks (Elrefaey et al., 2022; Yang et al. 2023). Other technologies can also enhance the virtual meeting to ensure the safety of information shared regarding the project quality and services without physical interaction, including digital twin, blockchain, etc. (Lu et al., 2022). In the pandemic era, virtual meeting is capital intensive but an efficient way to communicate among experts. This reduces the risks associated with travelling to different regions to meet regarding the project quality and services throughout the QA process.

CMM4 follows next, with sentiments comprising 21.20% negativity, 21.20% neutrality, and 57.60% positivity, as regarded by the experts. The CMM4 has impacted the QA, which has been largely positive. The negative impact of CMM4 can be associated with the low construction output and services due to the small number of workers required at workplaces. Though the limited number of onsite workers may minimise the pandemic spread, it also reduces the construction outputs and services throughout the QA process required to perform work and services. This then may cause delays in the project, affecting the overall project cost and quality because procedures may now take longer than expected due to the limited capacity of workers. This may also lead to work overload on multi-skilled workers throughout the QA process. However, it is important also to note the opportunity created by CMM4, which pushes organisations to develop innovative managerial strategies to manage the workforce throughout the QA process. Organisations may consider running multiple working shifts, but it must be done carefully to ensure information relating to quality is communicated properly throughout the QA process, from the design to the project completion (Araya, 2021). Organisations may also adopt working from home regarding the nature of a specific service. Digital technologies, such as smart robots and other machines, may cautiously be adopted to perform tasks throughout the QA process. The opportunities created, if harnessed properly, could ensure the continuity of QA amid the pandemic, regardless of the negative impact that surfaces.

The remaining CMMs have also impacted the QA with regard to the sentiment levels (see Appendix E). First, CMM1, throughout the QA process, has reduced the physical collaborations by reducing the number of workers coming into contact (Johnson et al., 2020). Hence, this affects the highly collaborative nature of the QA. CMM2 has interrupted the construction industry supply chain, impacting the QA activities. The supply of materials is delayed amidst the pandemic, affecting the project quality (Allen-Coghlan and McQuinn, 2020). Moreover, the CMM2 causes a delay in construction activities due to the halting of site activities, impacting construction progress and quality. This aligned with interviewees C and L when they mentioned that

"Due to the government's COVID-19 lockdown policy, we employees cannot be at work for a long time."

- *(Interviewee C, Quality Engineer)*

"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."

- *(Interviewee L, Quality Engineer)*

CMM3 has adversely affected workers travelling offshore to check and validate construction works in different countries. This affects services such as QA of international projects, causing delays in task executions (Kwok et al., 2021). This brought into line with interviewee F when he claimed that

"Restrictions on travel have had a serious impact on the departure of in-country operatives to resume work and carry out their work. 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."

- *(Interviewee F, Quality Inspection Officer)*

CMM6 incurs extra cost and time, which, if not handled carefully from the planning stage of the project, may affect the quality of satisfying the client in terms of cost and time. This was affirmed by interviewee J by mentioning that:

"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."

- *(Interviewee J, Quality Officer in charge of logistics)*

CMM1, CMM2, CMM3, and CMM6 have also created opportunities to develop innovative strategies to ensure the continuity of QA. This can be attributed to the improvement in the longstanding inadequate collaborations and communication among construction experts throughout the QA process through the adoption of digital technologies. This supports the statement by interviewees G, I, and K by mentioning that

"The greatest opportunity would be to demonstrate the importance of skilled workers. Because of the frequent stoppages, many projects are now not allowed to be worked on by new people because they are slow. So, the importance of skilled workers increases, and it would definitely be good to have skills that can assist with quality control."

- *(Interviewee G, Onsite quality inspection officer)*

"Under the epidemic prevention and control policy, if the management personnel cannot be present, fully automated and digital quality management is very necessary."

- *(Interviewee I, Director of Quality Management System Department)*

"The main impact is on quality management personnel, as they are restricted by the government's epidemic prevention and control policies."

- *(Interviewee K, Supply chain manager)*

The lesson learned from the impacts of the CMMs can positively re-organise the QA process by enabling flexible approaches (Ogunnusi et al., 2020; Onubi et al., 2021) and smooth project delivery techniques (Rees-Evans, 2022). The opportunities created can improve the QA process by positioning it to be adequate for the post-pandemic era and endure the risks of future pandemics.

5.2 Individual Impacts of the CMMs on the QA of Cb-CLSC

Among the CMMs, using the means score analysis revealed lockdown (CMM2) (4.19) to have the highest central tendency based on the experts' responses, followed by quarantine days (CMM6) (4.04), and travelling restrictions (CMM3) (3.96). However, the criticality of CMMs' impact using the normalisation scores denoted the top three CMMs with high criticality, including CMM2, CMM5, and CMM7, and these need to be given much attention by organisations and the industry. Nonetheless, all the CMMs are considered critical in impacting the QA amid the pandemic. As critical as they are, it is also important to consider their degree of impact on QA practices. Subsequently, the study revealed that CMM5 possesses the highest contributory power to form CMM in impacting the QA after performing SEM-based multiple regression analysis. Following the CMM5 includes the CMM4, CMM1, CMM2, CMM7, CMM3, and CMM6.

5.2.1 Use of PPE (CMM5)

Directly, CMM5 (0.409, $P<0.050$) is revealed to have significantly contributed largely to the influencing power of the CMMs on the QA, considering the other CMMs. Indirectly, CMM5 is discovered to have a significant positive impact on the QA (0.386, $p<0.050$), and the specific indirect effects on specific QA practices across the QA process are revealed as significantly positive in impacting the QA. The impact of CMM5 on QA practices can be both positive and negative, and this has been discussed earlier. Supporting the findings of this study, other studies have suggested CMM5 to have a high impact on the construction industry amid the pandemic, which can be extended to QA practices. For instance, the side effect of nose and face masks have been reported. Rosner et al. (2020) revealed that workers are safer from the side effects of masks if removed. This can be attributed to the QA practices, where putting on masks for too long may affect the workers' ability to perform efficiently, especially when the worker has breathing issues. This affects the quality of the work and service processes involved in delivering a project to meet the client's needs. However, the CMM5 also creates the opportunity to achieve a safe environment for workers as well as improve the health and safety management of an organisation towards the QA process of delivering quality construction projects.

5.2.2 Workplace Capacity Limit (CMM4)
CMM4 directly and significantly contributes to the influencing power of CMMs on the QA with a positive path coefficient value of 0.319 ($P<0.050$). Indirectly, CMM5 is revealed to impact the QA, representing a significant positive path coefficient value of 0.301 ($P<0.050$). All the available QA activities across the QA process are revealed to be positively and significantly affected by the CMM4 indirectly. This parallels with Radzi et al. (2022), who reported the COVID-19 pandemic to have affected all activities in the construction industry. This extends to the QA practices. CMM4 is recommended to prevent the spread of the pandemic (ILO, 2020) in the construction industry. However, it also impacts QA practices by causing low construction output due to the reduced number of workers required at a workplace at a given time throughout the QA process. This may cause procedures and services to take longer than expected, impacting project time and quality. It may usually occur due to the unavailability of the full capacity of workers to execute tasks throughout the QA process, which also leads to work overload on the multi-skilled workers/experts.

5.2.3 Social Distancing (CMM1)
CMM1 directly and significantly contributes to the influencing power of CMMs with a positive significant path coefficient value of 0.306 ($P<0.050$) to impact the QA. CMM1 also indirectly affects the QA with a significant path coefficient value of 0.288 ($P<0.050$). This depicts that the QA has been affected, and this can be regarded as negative and opportunities, as previously discussed. This finding aligns with other existing studies, which have reported on the impacts of construction activities (Elabd et al., 2020; Onubi et al., 2021). With regards to the QA, CMM1 has disrupted the QA processes, which are highly collaborative due to strict compliance with the social distancing measures. This places significant constraints on carrying out QA practices and reduces workplace productivity. It can be attributed to the few workers allowed at a workplace at a given time, prolonging procedures throughout the QA process (Manning et al., 2021). As such, the processes of conducting QA with quality data may be affected due to the limited number of workers available to give information concerning the progress and status of projects.

5.2.4 Lockdown (CMM2)
CMM2 directly contributes to the influencing power of CMMs on the QA with a significant positive path coefficient value of 0.281 ($P<0.050$). Indirectly, CMM2 significantly affects the QA with a positive path coefficient value of 0.265 ($P<03.050$). CMM2 has been implemented through stay-home orders, curfews, and similar societal restrictions, effectively mitigating the COVID-19 pandemic (Lau et al., 2020). However, as discussed earlier, the impact can be regarded as negative and opportunity. This finding is consistent with Ling et al. (2022) who reported on the impact of the lockdown on the entire construction industry. Considering the QA process, CMM2 halts the QA activities, which include the experts travelling to audit and verify quality works and services in different regions. CMM2 also causes a reduction in the construction output, which affects construction progress and quality (Brown et al., 2020). This relates to the lockdown's impact on the supply chain of material in construction, which can cause a delay in QA activities, hence, impacting the QA activities.

5.2.5 Electronic/virtual meeting (CMM7)
CMM7 directly affects the influencing power of CMMs on the QA with a significant negative path coefficient value of -0.271 ($P<0.050$). This can be related to CMM7's indirect influence on the QA with a significant negative path coefficient value of -0.256 ($P<0.050$). CMM7 empowers communication and coordination, enabling workers in different physical locations to use their internet-connected devices to meet in the same virtual room (Webex, 2022). CMM7 has influenced QA activities during the pandemic by enabling experts/workers to communicate and share vital information throughout the QA process. CMM7 is noted to be expensive due to the cost of digital technologies needed to empower such meetings (Elrefaey et al., 2022). However, CMM7 helps minimise the spread of the pandemic by ensuring safe distance among the experts/workers. It also ensures a smooth and efficient sharing of information throughout the QA process to help

achieve the quality of information. This can be related to building information modelling technology, 5G networks, etc. CMM7 can be regarded as not having much negative impact on the QA. The only negative impact can be related to the increase in project cost due to the high cost of acquiring digital technologies and training workers. However, the positive impact, which is a major impact on QA, is the CMM7's ability to ensure the continuity of QA activities throughout the QA process without a physical presence on construction sites. This is ensured through the virtual meeting and sharing of information about cross-border construction projects' quality.

5.2.6 Travelling Restrictions (CMM3)
Directly, CMM3 affects the influencing power of CMMs on the QA with a significant positive path coefficient value of 0.242 ($P<0.050$). CMM3 indirectly impacts the QA with a significant path coefficient value of 0.229 ($P<0.050$). Restrictions on travelling are enforced to minimise the spread of the pandemic. However, they have impacted the construction activities, especially the QA practices. This can be attributed to the delays in task executions caused by travelling restrictions, particularly where workers/experts must travel offshore to check and validate the quality of construction works and services in different regions/borders (Kwok et al., 2021). This leads to slowing down the inspection and validation works throughout the QA process. However, this has also compelled organisations to strategically plan activities throughout the QA process to avoid delays and devise innovative means to ensure the continuity of QA practices without travelling across borders to get the information relating to quality physically. Nevertheless, organisations need to consider the risks associated with such means due to information security and reliability by always ensuring a reliable and single source of information.

5.2.7 Number of Days for Quarantine (CMM6)
CMM6 directly impacts the inducing power of CMM7 on the QA with a significant positive coefficient value of 0.205 ($P<0.050$). However, its indirect influence on the QA is revealed with a significant positive path coefficient value of 0.194 ($P<0.050$). CMM6 separates and restricts workers/experts exposed to the pandemic from moving to determine whether they become well whilst reducing the risk of infecting others (CDC, 2017; Brooks et al., 2020). CMM6 may impact the QA with extra cost and time throughout the QA process if not handled carefully from the planning phase of cross-border construction projects. This may be unpleasant when organisations and experts undergo quarantine (Brooks et al., 2020). Organisations, therefore, need to plan consciously throughout the QA process considering the quarantine days to avoid delays to site activities and cost increments.

5.3 Combined Impacts of the CMMs on QA of Cb-CLSC
Overall, all the CMMs contribute to the influencing power of CMM on QA at a determination coefficient value (R^2) of 87.80%. This reflects how the CMMs combine to predict a unified impact on the QA. The study revealed that the CMMs had impacted the QA with a significant positive strong path coefficient of 0.944 ($P<0.050$) at R^2 of 89.10%; hence, retaining the proposed hypothesis ($\mathbf{H_{C1}}$), as hypothesised in Section 2.3. This reflects the impacts of the CMMs on the QA and has been felt among the QA practices with positive path coefficient values ranging from 0.980 to 0.993 at R^2 ranging from 96.10% to 98.70%. Indirectly, all the CMMs significantly impact QA practices. The relevant correlations between the CMMs have been positive and negative, depicting how the CMMs react among themselves. Finally, the model portrayed the absence of multicollinearity issues and suitable AVE and CR; hence, making the result accepted.

Though the impacts have been recorded as negative and opportunities, the study has revealed the extent of the impacts of the CMMs, which can be recorded as 89.10% on the QA with a strong positive correlation. Among the CMMs, attention needs to be given to CMM5, CMM4, and CMM1, which are revealed to have contributed largely to the influencing power of the CMM's impacts on the QA. However, it is also important to note that the impact is not solely negative but also the opportunities capable of re-organising the QA activities and ensuring a safe environment throughout the QA process. This aligns with other studies that have generally reported on the positive impact of the pandemic on the construction industry (Goh et al., 2022). The CMMs established, therefore, have empowered construction organisations to develop innovative approaches enabled by technology to ensure the continuity of QA activities through the QA. These practices may position the QA adequately during and after pandemics. Nonetheless, the impact of the CMMs on the QA is recognised by exploring the challenges and harnessing the created opportunities to improve the adequacy of QA in the pandemic era.

5.4 Theoretical and practical contributions

Theoretically, the study candidly and empirically evaluates the CMMs to understand how they have impacted the QA of Cb-CLSC. This provides a reference to the academia and industry researchers to continue the studies on how pandemic policies influence specific construction project activities by considering the uniqueness of each activity. This could also direct researchers to devise innovative strategies to ensure adequate QA systems in construction projects by considering the liable influence of the pandemic policies. The finding also enriches the extant literature on QA, Cb-CLSC and the COVID-19 pandemic in the construction industry by creating better understanding of how the COVID-19 pandemic policies have QA activities in construction.

Practically, the result deepens the understanding of the impact of the pandemic policies (CMMs) on QA to the construction project quality management front-liners and policymakers. This knowledge may help industry practitioners effectively and innovatively consider the effect of pandemic policies during the planning phase of construction project activities to deliver quality products during pandemics. Overall, this study provides a better understanding of how the pandemic policies, such as CMMs, have impacted QA and can aid in formulating planning and operational decisions to adequately position the QA for the post-pandemic era and to endure the risks of future pandemics. This could inform the players on the likely challenges of QA activities and creates policies to overcome the challenges and the associated effect when another pandemic occurs.

6 Conclusions

This study evaluated the impact of the CMMs on the QA of Cb-CLSC, which has received limited attention among studies for the past three years. Meanwhile, understanding these complexities could assist the construction project sector to be more innovative in adapting to the challenges created by the pandemic and survive future pandemic effects to deliver quality construction projects. An embedded mixed-method approach is adopted, comprising of a desk literature review, an online survey from 150 experts from different economies across the globe, and eight expert interviews.

The study confirmed that CMMs have not only impacted the QA negatively but also influenced the positioning of the QA for the post-pandemic era and probably to survive the risks of future pandemics. Among all the identified CMMs, the top three critical measures include "lockdown (CMM2)", "use of personal protective equipment, such as nose masks, disinfects, etc. (CMM5)", and "electronic/virtual meetings (CMM7)". However, CMM5 possesses the highest contributory power to form CMM in impacting the QA, and this can be regarded as largely positive by strengthening health and safety management systems. Its negative impact lies with the project cost increment and the inconveniences of using nose and face masks. Overall, all the CMMs contribute to the influencing power of CMM on QA at R^2 of 87.80%, reflecting how the CMMs have combined with having a unified impact on the QA of Cb-CLSC.

The findings of this study depict significant theoretical and practical contributions to understanding how the COVID-19 policies have impacted the construction industry, specifically cross-border construction. This could aid in formulating planning and operational decisions to adequately position the QA for the post-pandemic era and to endure the risks of future pandemics. This area of study has been given limited attention among prior studies during the pandemic.

The study is associated with limitations worth mentioning. A sample size of 150 experts was relied on to generate the outcome of this study. This is due to the specific experts needed from different economies across the world and the difficulty in reaching them in a limited time. Future research could extend the research to other economies, not mentioned in this study, and adopt rigorous tools to evaluate the influence of the pandemic policies on the QA, taking lessons from this study. Nevertheless, this study's profound insights and relevant outcomes remain due to the candid and rigorous analysis tools adopted through the embedded mixed-method approach by engaging experts from different economies.

References

Adabre, M.A., Chan, A.P., Darko, A., Osei-Kyei, R., Abidoye, R. and Adjei-Kumi, T. (2020). Critical barriers to sustainability attainment in affordable housing: International construction professionals' perspective. *Journal of Cleaner Production*, *253*, p.119995.

Allen-Coghlan, M., and McQuinn, K. (2020). *Property prices and COVID-19 related administrative closures: What are the implications?* https://www.esri.ie/system/files/publications/WP661_0.pdf.

Araya, F. (2021). Modelling working shifts in construction projects using an agent-based approach to minimise the spread of COVID-19. *Journal of Building Engineering*, *41*, p.102413.

Bagozzi, R.P. (1994). Structural equation models in marketing research: Basic principles. *Principles of marketing research*, *3*(1), pp.7-385.

Baker, M.G., Peckham, T.K. and Seixas, N.S. (2020). Estimating the burden of United States workers exposed to infection or disease: a key factor in containing risk of COVID-19 infection. *PloS one*, *15*(4), p.e0232452.

Barclay, D.W., Higgins, C.A. and Thompson, R. (1995), The partial least squares approach to causal modeling: personal computer adoption and use as illustration, *Technology Studies*, 2(2), pp. 285-309.

Bentler, P.M. and Wu, E.J. (2005), *EQS 6.1 for Windows, Multivariate Software*, Encino, CA.

Brooks, S.K., Webster, R.K., Smith, L.E., Woodland, L., Wessely, S., Greenberg, N. and Rubin, G.J. (2020). The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *The lancet*, 395(10227), pp.912-920.

Brown, S., R. D. Brooks, and Dong, X.S. (2020). *Impact of COVID-19 on construction workers and businesses*. https://stacks.cdc.gov/view/cdc/95397.

Cabaniss, K., 2002. Computer-related technology use by counsellors in the new millennium: A Delphi study. *Journal of Technology in Counselling*, *2*(2).

CDC (2017). *Quarantine and isolation.* 2017. https://www.cdc.gov/quarantine/index.html.

Chung, H.W. (2002). *Understanding quality assurance in construction: a practical guide to ISO 9000 for contractors*. Routledge.

Cleave, P. 2020, *What Is a Good Survey Response Rate?* https://www.smartsurvey.co.uk/blog/what-is-a-good-survey-response-rate#:~:text=By%20contrast%2C%20a%20survey%20response,relationship%20between%20the%20business%20and.

Creswell, J. W., and Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.

Designbuildings (2021). Desk Study, https://www.designingbuildings.co.uk/wiki/Desktop_study.

Dworkin, S.L. (2012). Sample size policy for qualitative studies using in-depth interviews. *Archives of sexual behaviour*, 41(6), pp.1319-1320.

Elabd, N.M., Mansour, Y.M. and Khodier, L.M. (2020). Social distancing in construction: investigating the role of technologies in supporting remote management. *Journal Of Engineering and Applied Sciences*, *67*(8), pp.2073-2091.

Elrefaey, O., Ahmed, S., Ahmad, I. and El-Sayegh, S. (2022). Impacts of COVID-19 on the Use of Digital Technology in Construction Projects in the UAE. *Buildings*, *12*(4), p.489.

Eurostat (2022). *Impact of Covid-19 crisis on construction*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Impact_of_Covid-19_crisis_on_construction.

Ghansah, F.A. and Lu, W. (2024), Managerial framework for quality assurance of cross-border construction logistics and supply chain during pandemic and post-pandemic: lessons from COVID-19 in the world's factory, *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-10-2023-1050.

Ghansah, F.A. and Lu, W. (2023). Responses to the COVID-19 pandemic in the construction industry: a literature review of academic research. *Construction Management and Economics*, pp.1-23.

Ghansah, F.A., Lu, W., and Ababio, B.K., (2023). Quality assurance of cross-border construction logistics and supply chain during the COVID-19 pandemic: evidence from the Hong Kong–Mainland China links. *International Journal of Logistics Research and Applications*, pp.1-21.

Ghansah, F.A, Lu, W., and Ababio, B.K. (2024). Modelling the critical challenges of quality assurance of cross-border construction logistics and supply chain during the COVID-19 pandemic. *Engineering, Construction and Architectural Management.* https://doi.org/10.1108/ECAM-01-2024-0016, In press.

Goh, Y.M., Tian, J. and Chian, E.Y.T. (2022). Management of safe distancing on construction sites during COVID-19: A smart real-time monitoring system. *Computers & Industrial Engineering*, *163*, p.107847.

Hair Jr, J.F., Sarstedt, M., Hopkins, L. and Kuppelwieser, V.G. (2014). Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. *European business review*.

Hamilton, T. (2023), *Quality Assurance vs Quality Control – Difference Between Them*, https://www.guru99.com/quality-assurance-vs-quality-control.html, Assessed: 11/04/2023.

Ijasan, K. and Ahmed, V. (2016). Studentification and the housing needs of international students in Johannesburg: an embedded mixed methods approach. *In Research methodology in the built environment* (pp. 149-166). Routledge.

ILO (2020) *In the Face of a Pandemic: Ensuring Safety and Health at Work*, ILO, Geneva.

ISO (1994) *Quality management and quality assurance—Vocabulary, International Organization for Standardization*.

Khan, A.H., Azhar, S. and Mahmood, A. (2008) August. Quality assurance and control in the construction of infrastructure services in developing countries–a case study of Pakistan. In *First International Conference on Construction in Developing Countries (ICCIDC-I)*.

Kline, R.B. (2015). *Principles and practice of structural equation modelling*. Guilford publications.

Kum, Y.T., Yap, J.B.H., Lew, Y.-L. and Lee, W.P. (2023), "Transforming construction health and safety management during COVID-19 pandemic using innovative technologies: PLS-SEM approach", *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-08-2022-0780.

Kwok, W.C., Wong, K.C., Ma, TF, Ho, KW, Fan, L.W.T., Chan, K.P.F., Chan, S.S.K., Tam, T.C.C. and Ho, P.L. (2021). Modelling the impact of travel restrictions on COVID-19 cases in Hong Kong in early 2020. *BMC public health*, *21*(1), pp.1-8.

Muheeb, B. (2021), *Literature Review / Desk Research: The Research Roadmap*, https://www.linkedin.com/pulse/literature-review-desk-research-roadmap-bashir-muheeb.

OECD (2020), *The territorial impact of COVID-19: Managing the crisis across levels of government*, https://www.oecd.org/coronavirus/policy-responses/the-territorial-impact-of-covid-19-managing-the-crisis-across-levels-of-government-d3e314e1/.

Ogunnusi, M., Hamma-Adama, M., Salman, H. and Kouider, T. (2020). COVID-19 pandemic: the effects and prospects in the construction industry. *International journal of real estate studies*, *14*(Special Issue 2).

ONS (2021), *Construction output in Great Britain: December 2020, new orders and Construction Output Price Indices, October to December 2020: December 2020,* https://www.ons.gov.uk/businessindustryandtrade/constructionindustry/bulletins/constructionoutputingreatbritain/december2020#annual-construction-output-growth-in-2020.

Onubi, H.O., Yusof, N., Hassan, A.S. and Bahdad, A.A.S. (2021), Forecasting the schedule performance resulting from the adoption of social distancing in construction projects, *Engineering, Construction and Architectural Management*, https://doi.org/10.1108/ECAM-07-2021-0632.

Ott, R. L., and M. T. Longnecker (2015). *An introduction to statistical methods and data analysis*. Toronto: Nelson Education.

Pallant, J. (2001). *SPSS survival manual: A step by step guide to data analysis using SPSS for Windows (versions 10 and 11): SPSS student version 11.0 for Windows*. Open University Press.

Pamidimukkala, A., Kermanshachi, S. and Jahan Nipa, T. (2021). Impacts of COVID-19 on health and safety of workforce in construction industry. In *International Conference on Transportation and Development 2021* (pp. 418-430).

Pilatowska, J. (2021). *How is cross-border logistics helping ecommerce to grow?* https://linkercloud.com/blog/ecommerce/how-cross-border-logistics-is-helping-e-commerce-to-grow#:~:text=What%20is%20cross%2Dborder%20logistics,international%20legal%20and%20tax%20regulations.

PMBOK (2017), *A Guide to the Project Management Body of Knowledge (PMBOK Guide) (Project Management Institute),* Project Management Institute, 6th Edition, Inc. USA.

Rees-Evans, D. (2022). *Covid-19 and Construction Learning lessons from the Covid-19 pandemic to strengthen the construction industry*, The Chartered Institute of Building, UK, https://www.ciob.org/media/1541/download.

Rosner, E. (2020). Adverse effects of prolonged mask use among healthcare professionals during COVID-19. *Journal of Infectious Diseases and Epidemiology*, 6(3), p.130.

Rossiter, J.R. (2002). The C-OAR-SE procedure for scale development in marketing. *International journal of research in marketing*, *19*(4), pp.305-335.

Sadeh, H., Mirarchi, C., Shahbodaghlou, F. and Pavan, A. (2023), "Predicting the trends and cost impact of COVID-19 OSHA citations on US construction contractors using machine learning and simulation", *Engineering, Construction and Architectural Management*, Vol. 30 No. 8, pp. 3461-3479. https://doi.org/10.1108/ECAM-10-2021-0953.

Saunders, M.N., Lewis, P. and Thornhill, A. (2009). Research methods for business students, 5th Edition: *Pearson Education India*. ISBN: 978-0-273-71686-0.

Sutterby, P., Wang, X., Li, H.X. and Ji, Y. (2023), "The impact of COVID-19 on construction supply chain management: an Australian case study", *Engineering, Construction and Architectural Management*, Vol. 30 No. 8, pp. 3098-3122. https://doi.org/10.1108/ECAM-10-2021-0942.

Webex (2022). *Virtual meetings in 2022: Everything you need to know*, https://www.webex.com/virtual-meetings-guide.html.

WHO (2020a). *Coronavirus disease (COVID-19).* https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/coronavirus-disease-covid-19.

WHO (2020b). *COVID-19 Dashboard. Geneva: World Health Organization*, https://covid19.who.int/.

WHO (2022). *WHO COVID-19 Dashboard*, https://covid19.who.int/?adgroupsurvey={adgroupsurvey}&gclid=CjwKCAjwo_KXBhAaEiwA2RZ8hGbOJrWQlQO-vuj6G41YFNxnmXcrPi7BHCdLYewY-J53XXU1asK9choCmi8QAvD_BwE.