Evaluating the critical resultant impacts of the COVID-19 pandemic on quality assurance of cross-border construction logistics and supply chain

Abstract

Purpose: This study aims to identify and examine the critical resultant impacts of the COVID-19 pandemic on quality assurance(QA) of Cross-border construction logistics and supply chain(Cb-CLSC).

Methodology: This is achieved via embedded mixed-method design pragmatically involving desk literature review, survey, and interviews from related experts within the Hong Kong SAR-Mainland China links. The design is further integrated with descriptive analysis, criticality test, rank agreement analysis, spearman correlation test, and sentiment analysis.

Findings: The study revealed 10 critical resultant impacts of the COVID-19 pandemic on the QA of Cb-CLSC, with the top three including "increased use of digital technologies(M10)", "worker absence, labour shortage and decrease in work rate(M3)", and "changes to how construction sites operate(M9)". Three underlying dimensions were discovered among all the critical resultant impacts: "cost-time-worker(CTW) related impacts", "work contract and operation(WCO) related impacts", and "work process(WP) related impacts". The critical resultant impacts are reflected in the time, cost, raw materials, and work processes, and this could manifest as negative as well as an opportunity to position the QA system to be adequate during the pandemic and post-pandemic era.

Originality: The study contributes to the knowledge body as it identifies and examines the critical resultant impacts of the COVID-19 pandemic on the QA of Cb-CLSC. This is original research with invaluable primary data collected in the form of surveys and interviews from construction quality experts within the Hong Kong–Mainland China links, known as the world's factory.

Keywords: COVID-19, Cross-border Construction Logistics and Supply Chain, Quality assurance.

1. Introduction

Cross-border Construction Logistics and Supply Chain (Cb-CLSC) encompasses interconnected activities and processes engaging contractors, suppliers, or vendors between 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 distinguishes QA from quality control, though the terms are occasionally used in tandem. 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). Quality control may 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. However, by the very nature of involving two or more economies in Cb-CLSC, distinct challenges do arise especially in the case of QA.

QA enables improvements in 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 the construction processes in Cb-CLSC, it regulates the conduct of different activities and prevents side-stepping (Patel and Pitroda, 2021). 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, making QA a complex practice with concerns such as being time-consuming, laborious, and prone to numerous human errors.

The intricacy of performing QA 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), they have also impeded the movement between economies during QA, disrupting the construction supply chain. This is due to stringent mitigation measures, including social distancing, lockdown, travelling restrictions, and workplace limited 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.

Academia, in partnership with the industry, has reported on the impact of COVID-19 on the construction industry from various perspectives, such as the general construction industry (Ogunnusi et al., 2020), the health and safety of the construction workforce (Pamidimukkala et al., 2021), and the use and adoption of digital technologies (Leontie et al., 2022). Onubi et al. (2022) analysed the impacts of the pandemic on health and safety management by moderating the effects of the project size on the relationship between the safety protocols and the economic performance of projects. Soliman et al. (2022) also examined the pandemic's impact on workforce management by considering labour's motivational factors and construction productivity. Sharma et al. (2022) focused on the survivability of sustainable supply chains during the pandemic and post-pandemic by developing an enhancement framework. However, the critical resultant impacts imposed by the pandemic on the QA of Cb-CLSC are still unclear. Tackling this issue involves identifying and understanding the critical resultant impacts. Ghansah et al. (2023) explored the critical areas of QA and examined their sentiments amid the pandemic, considering Cb-CLSC. Nevertheless, the critical resultant impacts of the pandemic on the QA of Cb-CLSC have still not been clearly explored. Exploring these critical resultant impacts contributes to understanding and developing resilience to adequately position the QA for the post-pandemic era and endure the risks of future pandemics. This informs the industry players on the likely impacts of pandemics on construction QA and creates policies to overcome the critical resultant impacts when another pandemic occurs.

This study, thus, examines the critical resultant impacts of the COVID-19 pandemic on the QA of Cb-CLSC. The specific objectives are (1) to empirically identify the critical resultant impacts and (2) to understand the sentiment levels of the critical resultant impacts. These are achieved by engaging experts from the Hong Kong SAR – Mainland China links via an embedded mixed-method approach using expert online surveys and interviews. The findings contribute to knowledge by identifying the critical resultant impacts of the pandemic on QA and their sentiment level. This may guide researchers to further the QA in the construction industry. It may also assist the practitioners and policymakers in developing resilience toward positioning the QA adequately for the post-pandemic era and enduring the risks of future pandemics. The paper is structured as follows: introduction, literature review on QA of Cb-CLSC during the COVID-19 pandemic, research method, analysis and findings, discussion, and conclusion.

2. QA of Cb-CLSC

Cb-CLSC involves important interrelated construction activities such as duties, border crossing, track record, and proper transportation (Pilatowska, 2021), and this promotes international trade and the construction market. For this study, Mawhinney's (2008) definition of Cb-CLSC is adopted due to its succinctness and understanding, and the definition is "where one company, resident in one country, performs construction works in another country." Construction activities are carried out by different subjects from different economies, where the subject may refer to legal persons or multi-national firms.

QA, according to the project management body of knowledge [PMBOK] (2017; 2021), is part of the project quality system of an organisation, and it ensures that project deliverables meet planned quality standards. The ISO (1994) well-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 with literature. As QA focuses on improving processes and methodologies 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) by engaging specific teams that test the products (ReQtest, 2016). Quality control may be a significant part of the QA processes toward a mega project, where individual completed sub-works are inspected and tested to ensure quality before moving to the next sub-works. QA and quality control, therefore, work together to satisfy the quality expectations of a project under Cb-CLSC, but they have a different focus. Consequently, this study adopts ISO's (1994) definition of QA because of its international acceptance and limits it to the Cb-CLSC.

Conducting QA is dependent on an organisation's quality management system, which embraces organisational resources, structure, and procedures (Khan et al., 2008; Qureshi et al., 2020). 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).

2.1 Influence of the COVID-19 outbreak

COVID-19 was declared a pandemic in March 2020 (WHO, 2020) and has gained a global transmission rate, recording 775,481,326 confirmed cases and 7,049,376 deaths [see Figure 1] (WHO, 2024). Countries worldwide have recorded their shares in this global transmission, which impacted the travel rate from one country to another due to death, fear, and panic. Thanks to visionary stakeholders, the transmission rate of the pandemic has been understood, and appropriate strategies and restrictions have been devised to ensure a safe workplace environment (WHO, 2020). As a result, some countries have noted the pandemic to be normal and have eased restrictions, while others are still adhering to restrictions and continue to handle the spread of the virus.

The COVID-19 mitigation measures, while stabilising the spread of the pandemic, have caused disruptions in activities across industries. Specifically, the pandemic has severely hit the construction industry (McKinsey and Company, 2020), along with mitigation measures such as lockdowns and travel restrictions (Ghansah and Lu, 2024a). This is due to the nature of activities, which requires interactions with co-workers and construction materials on sites (American Industrial Hygiene Association [AIHA], 2020). A study published in April 2020 reported that 8.3% of the 5.9 million construction workers were exposed to the virus once a month (Baker et al., 2020). The high risk of getting infected (Karwasra et al., 2021) has raised fear and panic in the construction industry during task execution. As such, Morris (2020) reported on challenges such as delay and suspension of projects, cancellation of planned and new projects, supply chain disruptions, operational restrictions, labour shortages, and financial problems. Greater concerns have been raised about cross-border projects, affecting related construction practices such as QA.

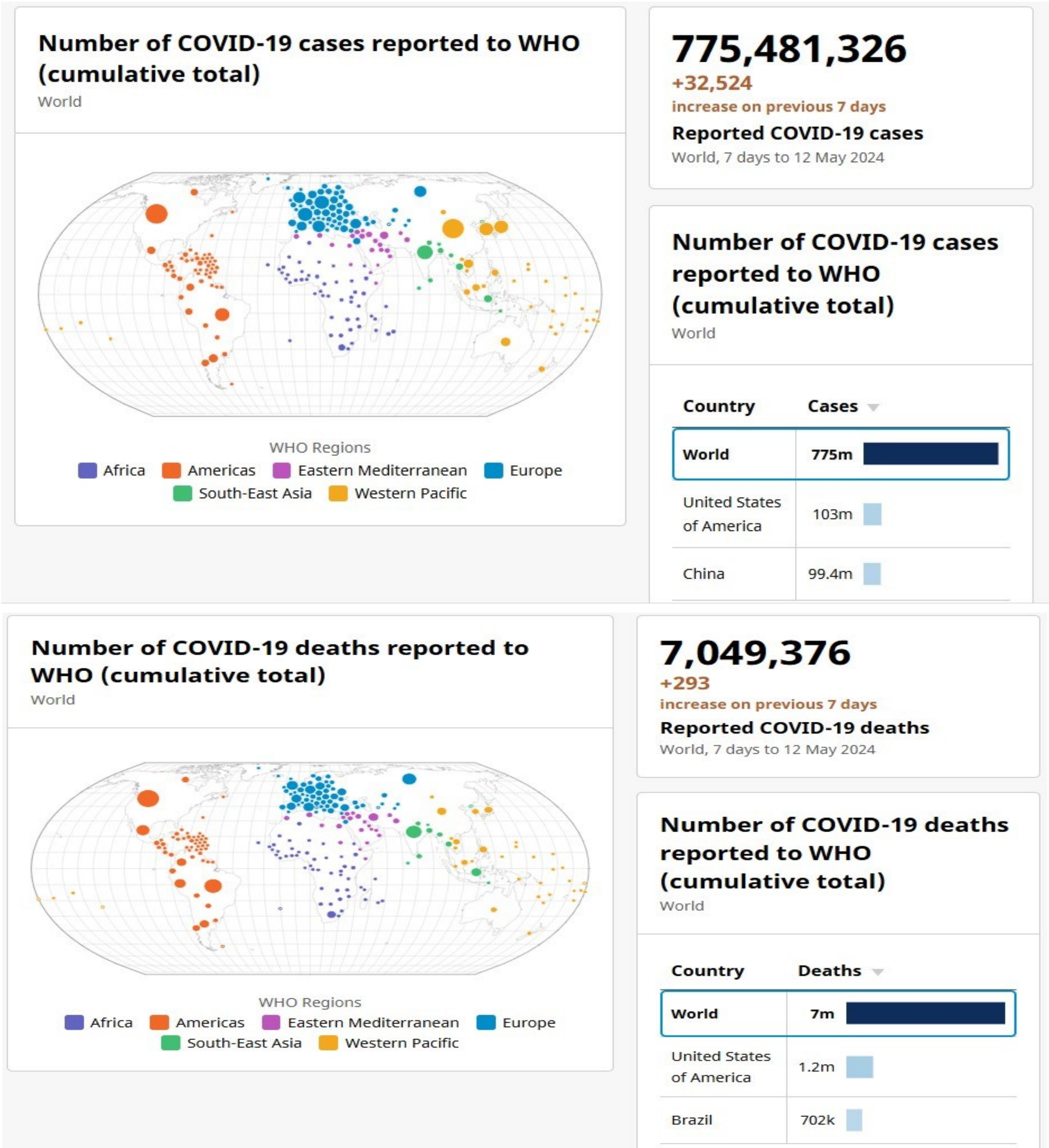

Figure 1: COVID-19 Cases and Deaths Across Countries (WHO, 2024)

2.2 Knowledge gap

Studies have reported on the impact of COVID-19 on the construction industry from various perspectives, such as the general construction industry (Ogunnusi et al., 2020), the health and safety of the construction workforce (Pamidimukkala et al., 2021), and the use and adoption of digital technologies (Leontie et al., 2022). Onubi et al. (2022) analysed the impacts of the pandemic on health and safety management by moderating the effects of the project size on the relationship between the safety protocols and the economic performance of projects. Soliman et al. (2022) also examined the pandemic's impact on workforce management by considering labour's motivational factors and construction productivity. Sharma et al. (2022) focused on the survivability of sustainable supply chains during the pandemic and post-pandemic by developing an enhancement framework. Other studies have also generally considered the impact of the pandemic on the construction project management lifecycle (Simpeh and Amoah, 2021; Gupta and Singh, 2021; Niroshana et al., 2022; Artpairin and Pinmanee, 2022). However, prior empirical studies have not yet examined the resultant impacts of the pandemic on QA toward positioning the QA system appropriately. Tackling this issue involves identifying and understanding the critical resultant impacts.

Thus, a comprehensive literature review of mostly peer-reviewed articles identified 11 potential resultant impacts of the COVID-19 on the QA, as illustrated in Appendix A. Among the potential resultant impacts, it is noted that the baseline can be drawn toward ISO 9000/9001, which stipulates the model for QA in design, development, production, installation, and service (Kafetzopoulos and Gotzamani, 2014; Budayan and Okudan, 2022). The study again adopted Deming's management model to define the potential resultants impacts in adequately fitting the Cb-CLSC (Deming, 1986; Anderson et al., 1994; Barone, 2022). There could be correlations among the potential resultant impacts. Based on this, this study aims to identify and examine the critical resultant impacts of the COVID-19 pandemic on the QA of Cb-CLSC by engaging experts in the Hong Kong SAR–Mainland China links, typically called the world's factory (Bajpai, 2022; Ghansah and Lu, 2024b). This knowledge would assist in developing strategies to position the QA adequately for the post-pandemic era and to endure the risks of future pandemics (Liu et al., 2022).

3. Research method

An embedded mixed-method design was pragmatically adopted for this study, where quantitative and qualitative data are collected simultaneously, and analysed within a traditional quantitative research design (Creswell and Clarke, 2017). This design was adopted due to the study's limited time in taking the data, and it allows the study to focus on the quantitative data but still needs to understand how the qualitative data further explains the findings, hence providing stronger evidence and more confidence in the findings (Edmond and Kennedy, 2017; Creswell and Clarke, 2017; Dovetail, 2023). Subsequently, the study followed four steps as detailed in Figure 2.

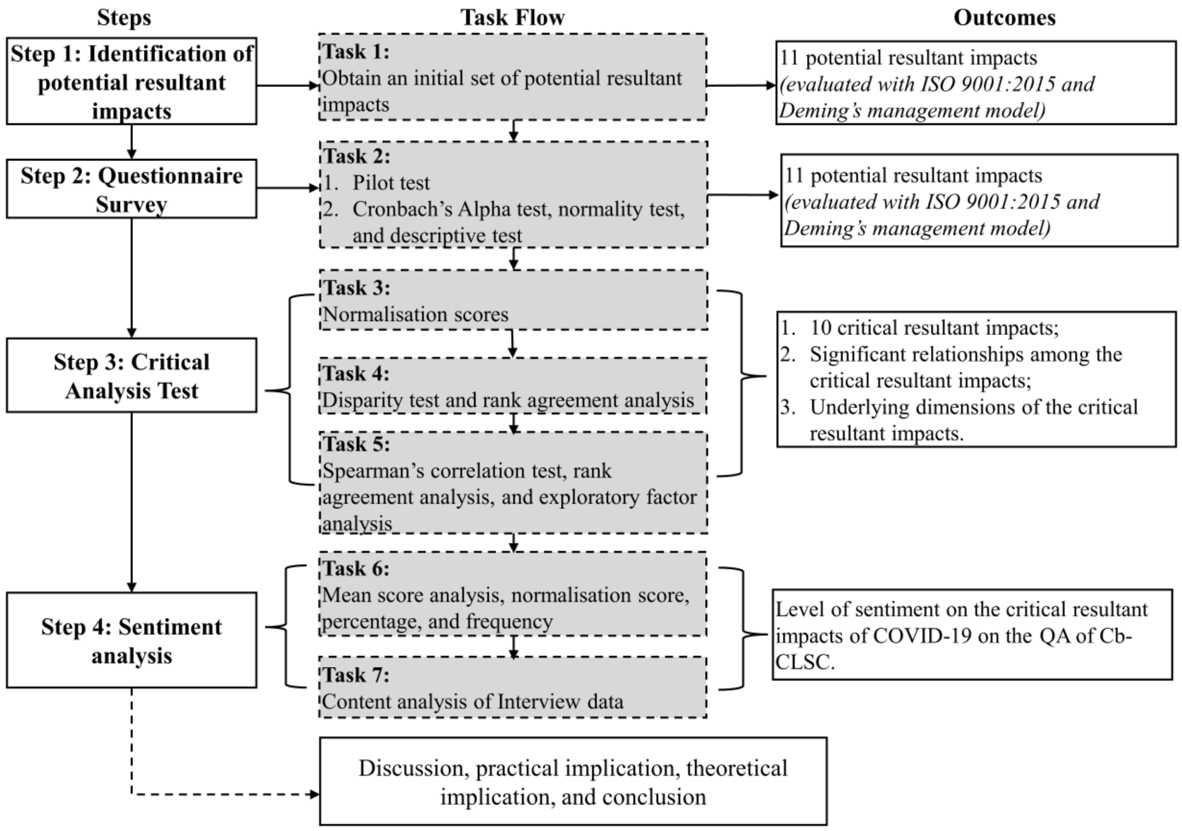

Figure 2: Research workflow (Source: Authors own work)

3.1 Identification of potential resultant impacts

A desk literature review was espoused for this study following two stages, and this involves an in-depth analysis of available literature on a particular research topic, including books, journals, conference articles, and other academic publications (Muheeb, 2021). The primary goal is to identify relevant data sources and assess the quality of data. Compared to other literature approaches, the desk literature review focuses on swiftly identifying the relevant sources and evaluating the available literature to identify key elements (Muheeb, 2021; Designbuildings, 2021). Desk literature review is often an initial step in the research process (Designbuildings, 2021), and for this study, it followed two rounds.

The first round included keywords (see Appendix A), which were entered to find relevant literature in Google Advance, Google Scholar, Scopus, and Web of Science databases. However, research on the resultant impacts of the pandemic on construction QA practices was lacking. In this preliminary search, it is necessary to identify the possible resultant impacts. Thus, the second round of research was performed to identify the potential resultant impacts among collected studies and tailor them to fit in the context of Cb-CLSC. The keywords included "Impact of COVID-19", "effect of COVID-19", "Construction activities", "Influence of COVID-19", "Built environment", "building industry", "quality assurance", and "quality management activities. Subsequently, 34 relevant academic articles were identified, including journal papers, and conference papers. To attain a comprehensive list of potential resultant impacts, ISO 9001:2015, Deming's management model, observation, and understanding were engaged to identify areas of QA and involve white papers and credible websites to understand the impact of the pandemic. These included the Centers for Disease Control and Prevention (CDC), the International Labour Organisation (ILO), and the Occupational Safety and Health Administration (OSHA). Consequently, the 11 potential resultant impacts were proposed (see Appendix A), and these would be examined to understand and identify their criticality and sentiments based on experts' views.

3.2 Data collection

Based on the comprehensive desk literature review, an initial questionnaire survey was prepared, capturing the 11 potential resultant impacts. The questionnaire survey could help determine the consensus level (Chiclana et al., 2015) on the potential resultant impacts in the context of Cb-CLSC, considering the experts' views from academia and the industry, and subsequently, determining their sentiments. In this study, the questionnaire survey allowed empirical data to be collected from the Hong Kong SAR–Mainland China links, ensuring experts' anonymity and data confidentiality. The Likert Scale was with the questionnaire survey used to rank the potential resultant impacts in terms of agreement and sentiment level due to its introduction of minimal response bias (Ghansah and Lu, 2024b), viz: 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).

A pilot study was then conducted to check the comprehensiveness and relevance of the resultant impacts by involving valuable responses from five experts (two quality inspectors [one from Hong Kong SAR and the other from Mainland China] and three academicians [two Assistant Professors from Hong Kong SAR and one Professor from Mainland China]). The valuable comments helped redefine the 11 potential resultant impacts into 10 (see Table 1). The result then informed the final questionnaire (see Appendix D). The interview questions were also piloted to have refined questions to attract experts' participation (see Appendix E). The data collection was preceded with an informed consent form to ensure the right expert with the right experience to participate, as illustrated in Appendix C.

Table 1: Well-defined list of potential resultant impacts after piloting (Source: Authors own work)

No.	Potential Resultant Impacts	References
M1	Extra cost incurred for quality assurance processes	1,2,3,4
M2	Delay in quality assurance processes	2,3,4,6,7,8,9,10,11,12
M3	Worker absence, labour shortage and decrease in work rate	4,9,12,13,14,15,16,17,18
M4	Contractual implications and disputes	6,19,20,21,22
M5	Workforce management and operational control process difficulties	11,19,22,23,24,25
M6	Work assessment difficulties	-
M7	Reorganisation of work processes	15,26
M8	Amendments and increase in organisational health and safety protocols	2,5,18,19,27,28,29
M9	Changes to how construction sites operate	-
M10	Increased use of digital technologies	8,3,30,31,32,33,34

For detailed references#, see Appendix B; (-) variables recommended by experts during piloting.

The study population included construction quality experts (both academia and industry practitioners [quality auditor, quality engineer, quality assurance/control manager, authorised person from the government, and client representative]) with relevant practical experience in Hong Kong SAR and Mainland China. As QA is a collective effort in construction organisations, "other" experts such as project managers, construction managers, site engineers/managers, and quantity surveyors were also engaged. This follows the concept of “expert” as defined by Cabaniss (2022). The experts were noted to be large, cutting across the different construction organisations or consultancy in Hong Kong and Mainland China, either private or public, industry experts or academia. Because there is no central database or comprehensive list of the construction QA experts, a non-probability sampling technique, including purposive and snowball sampling, were adopted by targeting the experts with knowledge and experience in the subject matter within Hong Kong SAR – Mainland China links.

Experts were considered if (1) they had extensive experience and were theoretically versed in the construction QA processes, (2) they had sufficient direct hands-on experience in construction QA, and (3) they had been involved in at least QA processes in their organisation. Overall, the expert must be in either Hong Kong SAR or Mainland China. The academic experts were also identified from highly recognised peer-reviewed journals which have contributed to the field of QA in the construction industry, whereas the industry practitioners were identified from construction companies in Hong Kong SAR and Mainland China. Websites of some professional associations in Hong Kong SAR and Mainland China were searched via LinkedIn and direct company websites to retrieve contact addresses of industry practitioners. Also, the snowball sampling technique was engaged for practitioners to help direct the researcher to other potential experts. The questionnaire survey was then distributed online using “Qualtrics XM” via personalised emails to allow online responses. This was conducted along with the interview questions and consent forms to pave the way for the interview session via a virtual platform using Zoom and WeChat. The duration for data collection lasted five to six months. Several reminders were sent throughout the data collection period, prompting the experts to respond to the survey and attend an interview session if available.

The number of questionnaires distributed within the enclave of Hong Kong SAR and Mainland China was not determined as humble appeals were requested to pass on the questionnaire to other appropriate experts who know the study’s context. However, an approximate value of 200 online questionnaires could be estimated for the distribution. Fifty-two (52) responses were finally retrieved from the experts. A limitation of this approach is the accurate estimation of the response rate, as some of the respondents possibly forwarded the survey to other potential experts. Nonetheless, it is generally suggested scientifically and agreed among scholars that a minimum sample size of 30 could be appropriate for analysis (Ott and Longnecker, 2015). Therefore, the 52 responses could be considered relatively high for analysis in this study. Nonetheless, 13 interviews were conducted to derive deep insight into the impacts of the pandemic on the QA practices of Cb-CLSC, meeting the minimum requirement OF 5-50 participants required for a qualitative study (Dworkin, 2012).

4. Data analysis and results

To conduct the analysis, the dataset was cleansed to remove uncompleted responses. Furthermore, the Statistical Package for the Social Sciences (IBM-SPSS), version 27, was adopted for the data analysis.

4.1 Demographic profile of experts

Figure 3 specifies the profile of the experts engaged in the survey, whereas Table 2 presents the profile of the interviewees. Overall, in the Hong Kong SAR–Mainland China links, the experts constituted 44.23% from Mainland China and 55.77% from Hong Kong SAR. 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 Hong Kong SAR–Mainland China links 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 ten years across Hong Kong SAR and Mainland China.

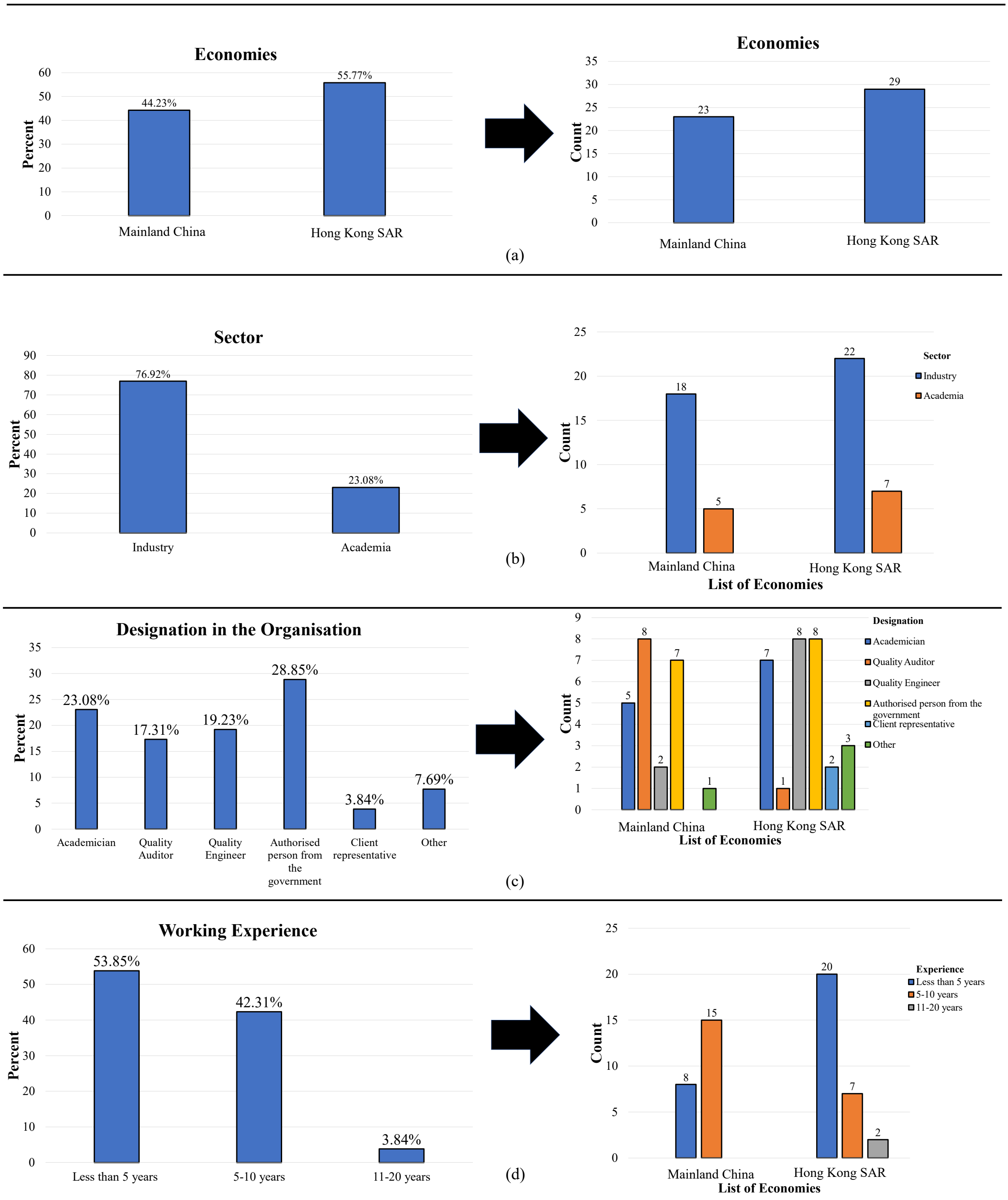

Figure 3: Experts' Profile (Source: Authors own work)

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

Interviewee	Designation	Qualification	Years of experience	Economy
A	Quality inspection officer	BSc	5	Mainland China
B	Quality inspection officer	MSc	2	Hong Kong SAR
C	Quality engineer	BSc	2	Mainland China
D	Quality inspection officer	MSc	5	Mainland China
E	Quality manager	MSc	4	Hong Kong SAR
F	Quality inspection officer	MSc	3	Mainland China
G	Onsite quality inspection officer	BSc	2	Mainland China
H	Quality manager	MSc	10	Hong Kong SAR
I	Director of Quality Management System Department	MSc	4	Mainland China
J	Quality officer (in charge of logistics)	BSc	2	Mainland China

K	Supply chain manager	MSc	6	Mainland China
L	Quality engineer	BSc	7	Hong Kong SAR
M	Quality engineer	MSc	3	Hong Kong SAR

4.2 Cronbach's Alpha test, normality test, and descriptive analysis

Internal consistency of the related dataset was determined with Cronbach's Alpha (CA) values (Pallant, 2001) as follows: level of agreement (0.902) and level of sentiment (0.835). Therefore, the dataset can be analysed further.

Using the Kolmogorov-Smirnov (K-S) test denoted that the related dataset was not to be normally distributed (see Appendix F); hence, non-parametric data. Using the means score analysis, the central tendency of the experts' views on the impacts was above 3.00, which is a measurement scale denoting neutral. This depicts the experts fairly agreeing with all the variables to represent the impacts of the pandemic on the QA. Similar inference can be achieved on a comparative descriptive analysis involving the two regions: Hong Kong SAR and Mainland China. A normalisation score (Ns) is adopted to measure the impact's criticality level. The Ns denoted all resultant impacts to be highly critical based on the experts' responses, as the Ns for each impact exceeded 0.500 (Adabre et al., 2020). A fairly good level of criticality was also noticed among the variables if considered on an individual border basis. Table 3 depicts the descriptive analysis outcome, including the mean confidence level at 95%.

4.3 Disparity Test

The degree of association is determined from the perspective of the academia and the industry within Hong Kong SAR–Mainland China links using the Mann-Whitney test. A null hypothesis, H0, is tested, which is:

there is no significant disparity vis-à-vis the level of agreement/sentiment on the resultant impact of the COVID-19 pandemic on the QA of Cb-CLSC among the two groups (academia and industry).

The H0 is rejected if the related P-value is ≤0.050, which is the significant level of the two-tail test. The results of the disparity test between academia and the industry with the critical resultant impacts of the pandemic on the QA using the Mann-Whitney test are shown in Appendix F.

4.4 Rank agreement analysis

The level of consensus between academia and the industry on the resultant impact is estimated to understand the agreement rate between the two sectors. The rank agreement is a quantitative method that uses the "rank agreement factor" (RAF). The RAF shows "the absolute difference in the ranking of factors between two groups" (Zhang, 2005): the academia (Group 1) and the industry practitioners (Group 2). Let the rank of a critical resultant impact within group one be R_{i1} while the same critical resultant impact within group two be R_{i2}. N is the number of QA practices in each component, and the number of groups (which in this case is 2) is represented by k. Then, (R_{i1}-R_{i2}) of a critical resultant impact is the difference in ranks obtained from the two groups – academia and industry. R_i of a critical resultant impact is the sum of the ranks of the critical resultant impact from academia and the industry. The following equations could be used to determine the RAF (Okpala and Aniekwu, 1988):

$$R_i = \sum_{i=1}^{N} Rij \qquad (1)$$

Where R_{ij} = sum of the ranks given to QA practice by the two different groups.

The mean value of the total ranks (R_{j2}) is given by

$$R_{ij} = \frac{1}{N}\sum_{i=1}^{N} Rij \qquad (2)$$

$$\text{RAF} = \frac{\sum_{i=1}^{n}|(\text{Ri1}-\text{Ri2})|}{N} \qquad (3)$$

The maximum rank agreement factor (RAF_{max}) is given by

$$RAF_{max} = \frac{\sum_{i=1}^{n}|(\text{Ri1}-\text{Rj2})|}{N} \qquad (4)$$

The percentage disagreement (PD) is given by

$$\text{PD} = \frac{\sum_{i=1}^{n}|(\text{Ri1}-\text{Ri2})|}{\sum_{i=1}^{n}|(\text{Ri1}-\text{Rj2})|} \times 100 \qquad (5)$$

The percentage disagreement (PD) is given by:

$$\text{PD} = \frac{\sum_{i=1}^{n} |(\text{Ri1} - \text{Ri2})|}{\sum_{i=1}^{n} |(\text{Ri1} - \text{Rj2})|} \times 100 \qquad (6)$$

The percentage agreement (PA) is given by:

$$\text{PA} = 100 - \text{PD} \qquad (7)$$

For this study,

$$\text{PD} = \frac{19}{45.2} \times 100 = 42.035\% = 42\%$$

Therefore, PA = 58%

Table 4 provides the rank agreement analysis on the ranking of the critical resultant impacts. Overall, the PA for the 10 critical resultant impacts of the pandemic on the QA of Cb-CLSC is 58%, showing a relatively good agreement between the experts from academia and the industry in the Hong Kong SAR–Mainland China links.

4.5 Spearman's Correlation Test and Exploratory Factor Analysis (EFA)

Spearman's correlation test is further conducted to understand the correlation between the resultant impacts based on the experts' level of agreement. This followed the rule of thumb with the coefficient between -1 and +1, where +1 denotes perfect positive correlation and -1 denotes perfect negative correlation (Sloan and Angell, 2015) situated at a statistical significance of P-value≤0.05. Table 5 shows the results of Spearman's correlation test.

The EFA is further conducted to explore the underlying groups of the resultant impacts of the pandemic on the QA. EFA is a robust technique for large sample sizes, with 50 as a reasonable absolute minimum (de Winter et al., 2009). Hence, with 52 as the sample size of this study, the EFA can yield good-quality results. To determine the suitability of the EFA, the Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity were first evaluated. The KMO is 0.774 and found acceptable since it meets the 0.500 threshold (Chan et al., 2018). The value of Bartlett's test was also noted as large (414.667) at a high-level significance (0.000). Hence, the values of the KMO and Bartlett's test give credence to the appropriateness of the data for EFA. With EFA, principal component analysis, with varimax rotation, was adopted to identify the underlying groups of the resultant impacts. Table 6 summarises the results of the EFA with all the 10 resultant impacts loaded (loadings >0.700). Three underlying components were extracted, explaining 81.065% of the variance. Therefore, a model with the three underlying components could satisfy the data from the academia and industry considering the Hong Kong SAR–Mainland China links. The components were further named based on a common theme of their underlying impact. Finally, conducting Cronbach's Alpha (CA) test on the three underlying components depicted an acceptable value of CA, denoting a satisfactory internal consistency (Pallant, 2001).

4.6 Sentiments analysis

Sentiment analysis is finally conducted on the critical resultant impacts to understand experts' views of the impacts on the QA based on the negative-neutral-positive model. The sentiment scores are estimated using the mean score and normalisation score to help have a fair idea of the impact along with percentage and frequency. Table 7 displays the sentiment analysis results from the survey.

Moreover, content analysis of the interview data is conducted to understand the real-life impact of the pandemic on the QA from experts in the Hong Kong SAR–Mainland China links. The content analysis findings are expected to complement the quantitative results from the sentiment analysis. The experts' responses are evaluated based on the area of impact across the QA process, including the material, work process, time, and cost. These areas can be aligned with the results of the survey, as illustrated in Appendix H, which also shows the specific responses of the experts on the resultant impacts of the pandemic on the QA.

Table 3: Results of the descriptive analysis (Source: Authors own work)

Code	Overall						Hong Kong SAR				Mainland China			
	Mean	SD	Ns	Rank	95% Confidence level for mean									
					Lower bound	Upper bound	Mean	SD	Ns	Rank	Mean	SD	Ns	Rank
M1	3.77	1.198	0.693	4	3.44	4.10	4.07	1.163	0.768	4	3.39	1.158	0.598	4
M2	3.67	1.200	0.668	5	3.34	4.01	4.00[a]	1.102	0.750	5	3.26	1.214	0.565	7
M3	4.19	0.864	0.730	3	3.95	4.43	4.31	0.806	0.770	3	4.04	0.928	0.680	3
M4	3.65	0.968	0.663	6	3.38	3.92	3.90	0.772	0.633	9	3.35[a]	1.112	0.588	5
M5	3.81	0.951	0.603	9	3.54	4.07	4.00[a]	0.886	0.667	7	3.57	0.992	0.523	9
M6	3.60	1.142	0.650	7	3.28	3.91	3.55	1.242	0.638	8	3.65	1.027	0.550	8
M7	3.56	0.938	0.520	10	3.30	3.82	3.72	0.882	0.573	10	3.35[a]	0.982	0.450	10
M8	3.90	1.015	0.633	8	3.62	4.19	4.03	0.981	0.677	6	3.74	1.054	0.580	6
M9	4.06	0.725	0.765	1	3.86	4.26	4.24	0.511	0.810	1	3.83	0.887	0.708	1
M10	4.50	0.577	0.750	2	4.34	4.66	4.59	0.568	0.795	2	4.39	0.583	0.695	2

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; Rank based on Ns; [a]Equal mean, wherein resultant impact with equal SD are ranked the same; also, resultant impact with low SD is ranked higher.

Table 4: Results of the rank agreement analysis (Source: Authors own work)

Code	Academia			Industry			Agreement Analysis		
	Mean	SD	Rank	Mean	SD	Rank	R_i	$\lvert(R_{i1} - R_{i2})\rvert$	$\lvert R_i - R_{j2}\rvert$
M1	3.75[a]	1.422	8	3.78	1.143	6	14	2	3.1
M2	3.92	1.443	4	3.60	1.128	8	12	4	1.1
M3	4.25	1.138	2	4.18	0.781	2	4	0	6.9
M4	3.42	1.165	10	3.73	0.905	7	17	3	6.1
M5	3.75[a]	1.055	7	3.83	0.931	5	12	2	1.1
M6	3.67	1.303	9	3.58	1.107	9	18	0	7.1
M7	3.83	1.030	5	3.48	0.905	10	15	5	4.1
M8	4.08	1.165	3	3.85	0.975	4	7	1	3.9
M9	3.83	1.030	5	4.13	0.607	3	8	2	2.9
M10	4.58	0.515	1	4.47	0.599	1	2	0	8.9
Total							$\sum_{i=1}^{n}(Ri) = 109$; $R_j = \frac{109}{10} = 10.9$	$\sum_{i=1}^{n}\lvert (Ri1 - Ri2) \rvert = 19$	$\sum_{i=1}^{n}\lvert (Ri1 - Rj2) \rvert = 45.2$

[a]Equal mean; [b]Equal SD, wherein resultant impacts with equal SD are ranked the same; also, resultant impact with low SD is ranked higher.

Table 5: Spearman correlation matrix (Source: Authors own work)

Code	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
M1	1.000									
M2	0.795**	1.000								
M3	0.630**	0.748**	1.000							
M4	0.606**	0.543**	0.452**	1.000						
M5	0.522**	0.541**	0.474**	0.597**	1.000					
M6	0.403**	0.475**	0.399**	0.454**	0.820**	1.000				
M7	0.684**	0.798**	0.583**	0.467**	0.643**	0.651**	1.000			
M8	0.673**	0.700**	0.841**	0.449**	0.522**	0.452**	0.694**	1.000		
M9	0.346*	0.253	0.364**	0.433**	0.390**	0.152	0.177	0.299*	1.000	
M10	0.257	0.183	.322*	0.090	0.093	0.017	0.229	0.397**	0.566**	1.000

For P-values [Sig. (2-tailed)], see Appendix G; **Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

Table 6: Results of the exploratory factor analysis (EFA) (Source: Authors own work)

Code	Component			CA	Mean score
	1	2	3		
Cost-Time-Worker (CTW) related impacts				0.918	**3.87**[3]
M1	0.834	-	-		3.77
M2	0.882	-	-		3.67
M3	0.825	-	-		4.19
Work contract and operation (WCO) related impacts				0.814	**3.69**[2]
M4	-	0.762	-		3.65
M5	-	0.789	-		3.81
M6	-	0.716	-		3.60
Work process (WP) related impacts				0.659	**4.01**[1]
M7	-	-	0.824		3.56
M8	-	-	0.887		3.90
M9	-	-	0.871		4.06
M10	-	-	0.840		4.50
Eigenvalue	5.520	1.560	1.027	-	-
Variance	55.196	15.596	10.273	-	-
Cumulative variance	55.196	70.792	81.065	-	-
Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy					0.774
Bartlett's Test of Sphericity Approx. Chi-Square					414.667
Degree of freedom					45
Significance					0.000

Extraction method: Principal component analysis; Rotation Method: Varimax with Kaiser Normalization; CA=Cronbach's Alpha

Table 7: Results of the sentiment analysis of the survey (Source: Authors own work)

Code	Sentiments				Sentiment score	Ns
	Negative	Neutral	Positive	SD		
M1	33(63.46%)	16(30.77%)	3(5.77%)	0.605	1.42	0.210
M2	37(71.15%)	13(25.00%)	2(3.85%)	0.550	1.33	0.165
M3	35(67.31%)	16(30.77%)	1(1.92%)	0.520	1.35	0.175
M4	23(44.23%)	28(53.85%)	1(1.92%)	0.537	1.58	0.290
M5	28(53.85%)	20(38.46%)	4(7.69%)	0.641	1.54	0.270
M6	23(44.23%)	24(46.15%)	5(9.62%)	0.653	1.65	0.325
M7	20(38.46%)	18(34.62%)	14(26.90%)	0.808	1.88	0.440
M8	16(30.77%)	19(36.54%)	17(32.70%)	0.804	2.02	0.510
M9	13(25.00%)	18(34.62%)	21(40.40%)	0.802	2.15	0.575
M10	13(25.00%)	4(7.69%)	35(67.30%)	0.871	2.42	0.710

Ns=Normalisation score= (actual mean–minimum mean)/ (maximum mean-minimum mean); SD = standard deviation

5. Discussion of findings

5.1 Criticality of the resultant impacts

The QA process has been impacted severely by the COVID-19 pandemic, pushing organisations to devise strategies to ensure the continuity of QA tasks. The central tendency agreement (means score) on the resultant impacts denoted the top three resultant impacts, namely the increased use of digital technologies (M10), worker absence, labour shortage and decrease in work rate (M3), and changes to how construction sites operate (M9). The criticality level (normalisation scores) of the impact was noted to be consistent with the mean score, as the top three result impacts with high criticality reflected M9, M10, and M3. However, M9 was revealed as the most critical as the pandemic has disrupted the operations on the construction sites, causing delays and halting the site operations (Aigbavboa et al., 2022) because continuing projects is considered impractical or unsafe (Chakaroun et al., 2021). The significant changes to construction operations have gone beyond safety and focused on remote work and digital tools to facilitate the continuity of QA tasks on projects. To add to the changes, a fully digitalised process has proved crucial for the continuity of the QA tasks in the pandemic era (Lu et al., 2022). Thus, changes in the site operations toward achieving the quality of cross-border projects have been disrupted, leading to the increment in the adoption rate of digital technology to ensure the continuity of QA activities, such as monitoring, inspection, auditing, verification, and so on.

Among the two economies (Hong Kong SAR and Mainland China) severely impacted by the pandemic, M9, M10, and M3 are still reflected as the top three critical resultant impacts if considered individually. However, all the 10 identified resultant impacts were noted as being critical across the individual economies. This is consistent with other economies, such as the United Kingdom (Jallow et al., 2021), Iraq (Al-Mhdawi et al., 2022b), United Arab Emirate (Sami Ur Rehman et al., 2022), Nigeria (Ogunnusi et al., 2020), Ghana (Agyekum et al., 2021) etc. as reported on the pandemic on the construction operations, which has close linkage with the QA process. The construction site operations are noted to have experienced changes that are attributed to the challenges created amid the pandemic (Oo et al., 2021; Aigbavboa et al., 2022). Throughout the QA process, the impact of the pandemic can be highly attributed to the changes incurred in the work processes and service toward achieving quality, followed by the increased rate of digital technology adoption and the rate of worker absence, causing labour shortage and work overload through the QA process (Jeon et al., 2022; Leontie et al., 2022; Elrefaey et al., 2022). The changes in the construction site operations influence the companies to reorganise the work process for QA activities to adapt to new conditions and ensure a safe working environment to prevent worker absence (Ghansah and Lu, 2024b). This implies that the resultant impacts of the pandemic on the QA influence themselves, resulting from the high linkage of the critical challenges imposed. Thus, organisations must be conscious of managing the resultant impacts by devising innovative strategies capable of considering the interrelationships between the difficulties created.

Based on the Mann-Whitney test, no significant disparity was noted in the critical resultant impacts. Also, a relative percentage agreement of 58% was discovered between industry and academics. Thus, the critical resultant impacts are perceived to reflect the study context. Evaluating the interrelationships among the critical resultant impacts using Spearman's correlation matrix revealed positive correlations, with the majority being significant at a p-value less than 0.01 or 0.05. The study revealed the strongest significant positive correlation between "amendments and increase in organisational health and safety protocols (M8)" and "worker absence, labour shortage and decrease in work rate (M3)", followed by "work assessment difficulties (M6)" and "workforce management and operational control process difficulties (M5)", and then "reorganisation of work processes (M7) and "delay in quality assurance processes (M2)". The strongest positive correlation (i.e., M8-M3) denoted that worker absence, which is linked to labour shortage, is likely to emerge if the existing health and safety protocols are ineffective in ensuring a safe environment in the QA process. This is consistent with Araya (2021) and Quezon (2021) regarding workers' absenteeism due to unsafe environments due to the pandemic. However, effectively amending the organisation's health and safety protocols throughout the QA processes toward mitigating the pandemic could create a safe environment to encourage workers to attend services with a quality-oriented focus. The result implies that the critical resultant impacts of the pandemic on the QA are positively correlated; therefore, organisations need to pay attention to their potential linkages when formulating policies and strategies to minimise the impact throughout the QA process.

5.2 Underlying dimensions of the critical resultant impacts

Further analysis with exploratory factor analysis denoted that the critical resultant impacts of the pandemic on the QA in the study's context can be categorised into three underlying dimensions, namely component 1: cost-time-worker (CTW) related impacts, component 2: work contract and operation (WCO) related impacts, and component 3: work process (WP) related impacts. A model with these underlying dimensions could satisfactorily reflect the resultant impact of the pandemic on the QA, explaining 81.065% of the total variance.

Component 1 (CTW) features three critical resultant impacts (M1, M2, and M3) reflecting the impact on cost, time, and the experts/workers throughout the QA process. The impact of the pandemic has been experienced largely by halting services and operations on construction projects, which has a high tendency to lead to schedule extension (Gamil and Alhagar, 2020), as well as attracting extra costs on the QA activities (Alsharef et al., 2021; Amoah et al., 2022) such as quarantine and health and safety cost, which provides safe environment and conditions throughout the QA processes. When conducting QA, the status of people/experts/workers is very important throughout the QA processes as they perform the services/works contributing to the quality of a cross-border project. However, the pandemic has unleashed fear in construction workers, causing panic due to the high infection rate and relatively high mortality rate (Liang et al., 2022). This leads to worker absence in performing services to quality, especially in an unsafe environment. To ensure the safety of workers/experts and continuity of work and services to avoid delay and extra cost, Lu et al. (2022) suggested using e-inspection 2.0, which ensures effective collaboration among workers from remote locations whilst ensuring transparency and data security. This couples with a good understanding of providing a safe environment for workers to execute works and services throughout the QA processes. A significant positive correlation exists among the critical resultant impacts (M1, M2, and M3), as CTW was ranked second among the components/dimensions with a mean score of 3.87. For instance, there is a significant positive correlation between the "extra cost incurred for QA processes" (M1) and "delay in quality assurance processes" (M2) ($\rho = 0.795$, $P = 0.000$), between M1 and "worker absence, labour shortage and decrease in work rate" (M3) ($\rho = 0.693$, $P = 0.000$), and between M2 and M3 ($\rho = 0.748$, $P = 0.000$). Overall, these correlations are coherent in measuring the same impact, and therefore, a systematic approach must be devised to manage them, considering the influencing power of the individual resultant impacts.

Component 2 (WCO) highlighted three resultant impacts (M4, M5, and M6), reflecting the impact of the pandemic on the contract binding the project and the operational process management toward achieving the required quality of a project. Contractual issues are likely to manifest due to inadequate processes in conducting QA amid the pandemic. The inadequacies manifest from the difficulties encountered in empowering workers to evaluate the quality of executed services and works (Zamani et al., 2021; Umar, 2022) throughout the QA process. Thus, this component appeared third among the underlying dimensions, with a mean score of 3.69. There exist significant positive correlations among the resultant impacts: between "contractual implications and disputes" (M4) and "workforce management and operational control process difficulties" (M5) ($\rho = 0.474$, $P = 0.000$), between M4 and "work assessment difficulties" (M6) ($\rho = 0.454$, $P = 0.001$), and between M5 and M6 ($\rho = 0.820$, $P = 0.000$). The correlations among the result impacts were noted to be positively influencing themselves and coherent. Thus, this must also be considered in developing systematic approaches to adequately position the QA when considering cross-border construction projects.

Component 3 (WP) highlights four resultant impacts (M7, M8, M9 and M10) reflecting the impact of the pandemic on the actual process of QA. This appeared first among the underlying dimensions, with a mean score of 4.01. It reflects the changes the QA process has undergone amid the pandemic, including the reorganisation of the work processes influencing the QA process (Onubi et al., 2021; Niroshana et al., 2022), as well as strengthening the health and safety protocols to create a safe environment for workers to execute works and services toward quality (Pamidimukkala et al., 2021). It also extends to the increase in the adoption rate of digital technologies to ensure the continuity of QA tasks, such as inspection, supervision, auditing, etc. (Lu et al., 2022; Leontie et al., 2022). This reflects the significant changes that have occurred throughout the QA process. However, among them exist significant positive correlations toward the coherence in impacting the QA process. Significant positive correlations exist between "amendments and increase in organisational health and safety protocols" (M8) and "reorganisation of work processes" (M7) ($\rho = 0.694$, $P = 0.000$), between "increased use of digital technologies" (M10) and "changes to how construction sites operate" (M9) ($\rho = 0.566$, $P = 0.000$), among others. This, therefore, implies that the changes in the QA process due to the pandemic could be attributed to health and safety, reorganisation of the work processes and digital technologies adoption, and they all correlate in ensuring the continuity of QA activities throughout the QA process.

5.3 Sentiments on the critical resultant impacts of the COVID-19

A sentiment analysis denoted that the resultant impacts of the pandemic on the QA can be regarded as positive and negative. The study revealed M2 as being associated with the strongest negative influence on the QA processes. However, M2 has also reflected neutrality and positivity that needs to be acknowledged. For this study, the neutral and positive effects are regarded as opportunities for a particular resultant impact. This is consistent with Ling et al. (2022) and Olatunde et al. (2022), when they regarded delay as a common impact on construction activities amid the COVID-19 pandemic. With regards to the QA process, the delay is likely to manifest from the travelling difficulties of workers/experts in performing the QA tasks (Aigbavboa et al., 2022; Dobrucali et al., 2022), as well as the disruptions in the supply chain (Jeon et al., 2022; King et al., 2022), which affect the distribution of raw materials throughout the QA process. As a result, changes have occurred in the QA processes, influencing organisations to position themselves adequately to continue conducting quality work and services amid the pandemic. The study revealed that M9 had the strongest positive impact throughout the QA process, followed by M10, M8, and M7. This result is consistent with the sentiments on the challenges, as previously discussed, revealing that organisations need to harness the opportunities of the created challenges to achieve positive impacts on QA. However, it is also critical to consider that the changes have also induced additional costs in the QA process, manifesting from the adopted digital technologies, the cost of orienting experts, and so on (Leontie et al., 2022; Elrefaey et al., 2022). The result reiterates that the pandemic's impacts have not been solely negative but have also pushed organisations to position themselves adequately to ensure the continuity of QA tasks throughout the QA process.

Assessing the interview data from experts in the domain revealed four main areas of the pandemic's impact on the QA process: costs, time, material, and work process. The work process of QA has been impacted by the pandemic, causing delays in testing, inspections, auditing, and communication. These, if not handled carefully, tend to halt and suspend projects. As such, interviewee B reaffirmed that projects are suspended, especially if quality testing is not conducted. This also can be extended to the unavailability of raw materials and workers in executing related services (Oey and Lim, 2021; Rankohi et al., 2022) throughout the work process of cross-border construction projects. Costs have also been impacted severely in the QA by the pandemic, and this stems from the disruptions caused in the supply chain, the adoption of technologies to ensure the continuity of QA tasks, and the cost of strengthening the health and safety management protocols in creating a safe environment for workers (Jeon et al., 2022; Al-Mhdawi et al., 2022a; Agyekum et al., 2022). Adopting digital technologies and strengthening the health and safety management system have had positive impacts; however, this can increase the project cost, which can be noted as a negative impact. Raw material availability across the work process to ensure quality execution services has also been impacted by the pandemic, which tends to cause delays (Dobrucali et al., 2022; Rankohi et al., 2022) throughout the QA process. Interviewee H reiterated this by expressing a positive correlation between the difficulties of raw material delivery and the slower pace of production operations throughout the QA process. Time has been severely impacted concerning the QA, which manifests in delays in the QA activities, such as inspections, auditing, etc. Interviewee M reaffirmed that site workers, who contribute to achieving quality projects, are delayed by inspectors if there is a confirmed case of the pandemic in the project team. The resultant impact of the pandemic on the QA can be reflected in the time, cost, raw materials, and work processes, and this could manifest as negative as well as an opportunity to position the QA system. Thus, the opportunities created must be harnessed to position the QA to be adequate to survive the post-pandemic era and endure the risks of future pandemics.

5. 4 Theoretical and practical implications

Theoretically, the results of this study enrich the extant literature on QA, Cb-CLSC, and the COVID-19 pandemic in the construction industry by identifying the critical resultant impacts and examining them to understand their sentiment levels. The top three critical resultant impacts of the pandemic on QA of Cb-CLSC include increased use of digital technologies (M10), worker absence, labour shortage and decrease in work rate (M3), and changes to how construction sites operate (M9). However, three underlying components discovered include cost-time-worker (CTW) related impacts, work contract and operation (WCO) related impacts, and work process (WP) related impacts. For instance, understanding the results, along with their sentiments, areas of the impacts and the opportunities, offers a clearer understanding of how the pandemic has influenced construction QA and the possibilities it has offered. This might also be used to guide researchers in developing innovative strategies to deal with the critical resultant impacts and ensure adequate QA during pandemics, as well as informing policies to overcome the critical impacts when another pandemic strikes.

Practically, the study provides valuable lessons from the COVID-19 pandemic by deepening the understanding of the resultant impact of the pandemic on the QA to the construction quality management front-liners and policymakers. This is achieved by identifying the critical resultant impacts of the pandemic on the QA and examining them to understand their sentiment levels, including the negative and positive sentiments, the areas of the impacts, and the created opportunities for the policymakers, decision-makers, and quality management experts. For example, the results inform the industry players of the likely impacts of pandemics on construction QA and create policies to overcome the critical impacts when another pandemic occurs. This provides a useful point of reference for policymakers, practitioners, and decision-makers in developing policies to improve the efficacy of QA during the pandemic and beyond.

6. Conclusions

This study identified and examined the critical resultant impacts of the COVID-19 pandemic on the QA of Cb-CLSC, which has received limited focus among prior studies. Exploring these resultant impacts contributes to understanding and developing resilience to adequately position the QA for the post-pandemic era and endure the risks of future pandemics. An embedded mixed-method design is adopted, comprising a desk literature review, an online survey from 52 experts across the Hong Kong SAR – Mainland China links, and 13 expert interviews.

The study revealed 10 critical resultant impacts of the pandemic on the QA, with the top three including increased use of digital technologies (M10), worker absence, labour shortage and decrease in work rate (M3), and changes to how construction sites operate (M9). Three underlying dimensions of the critical resultant impacts are revealed to be cost-time-worker (CTW) related impacts, work contract and operation (WCO) related impacts, and work process (WP) related impacts. A model with these dimensions explains 81.065% of the variance, reflecting the consequential impact of the pandemic on the QA. The sentiments on the critical resultant impact reiterated that the pandemic's impacts have not been solely negative but have also pushed organisations to position themselves adequately to ensure the continuity of QA tasks throughout the QA process. The critical resultant impacts can be reflected in the time, cost, raw materials, and work processes, and this could manifest as negative as well as an opportunity to position the QA system to be adequate during the pandemic and post-pandemic era.

The findings of this study depict significant theoretical and practical contributions to understanding how the COVID-19 pandemic has impacted the construction industry. This could provide a useful point of reference for researchers, policymakers, practitioners, and decision-makers in developing policies to improve the efficacy of QA during the pandemic and beyond.

This study has several limitations that should be highlighted. The study used a relatively small sample size to achieve the results, which may affect the generalizability of the findings. This is due to the specific experts needed across the Hong Kong SAR–Mainland China links and the difficulty in reaching them in a limited time. As a result, future research based on the Hong Kong SAR-Mainland linkages can consider a larger sample size and extend the study to identify the critical challenges imposed by the pandemic on the QA in the construction industry. This could provide more insight into operational decisions in delivering quality construction projects during pandemics. Moreover, future studies may expand the study to other economies and use varied rigorous analytical tools to identify and examine the critical resultant impacts of the pandemic on QA, taking lessons from this study. Nevertheless, the relevance and depth of this study's findings remain due to the candid and rigorous analytical tools adopted via the embedded mixed-method design.

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