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Covid-19 pandemic disruptions and environmental turbulence in architectural, engineering and construction project delivery space

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Abstract

Purpose- Firms in the architectural, engineering, construction and operations (AECO) sector continue to undertake projects in disruptive environment due to the Covid-19 pandemic. The purpose of this study is to explore environmental turbulence in AECO project delivery space and suggest mechanisms for enhancing resilience against future pandemics.

Design/methodology/approach-The study adopts the quantitative approach by administering 110 survey questionnaires to participants comprising project managers, site engineers, quantity surveyors, contractors and subcontractors.

Findings-The study identifies twenty-four Covid-19 disruptions linked to environmental turbulence categorised as scheduling, performance and productivity, project budget, supply chain, resource allocation and technological and regulatory- The study suggested resilient mechanisms for surviving in future pandemics.

Originality/value- This study enhances the understanding of environmental turbulence from the perspective of Covid-19 disruptions in AECO project delivery while the implementation of the resilient mechanisms improves capability of AECO firms against future pandemics.

Keywords: Turbulence, Covid-19, Architectural, Project, Construction, Environment

1. Introduction

Pandemics have created uncertainties, and rapid changes that lead to environmental turbulence (Poorolajal, 2021). Environmental turbulence refers to the instability, unpredictability and unexpected changes encountered by organisations (Miner *et al*., 2001). Environmental turbulence is characterised by increasing globalisation, intense competition, unpredictable international events, and rapid technological changes (Bhatt, 2010). Contrary to their negative impacts, environmental turbulence enhances the awareness of firms about the need to innovate and adopt new technologies (Madrid-Guijarro *et al*., 2009). Covid-19 has led to 3.8 trillion dollars loss in consumption, 147 million full-time job losses, and 2.1 trillion dollars loss of income (Lenzen *et al*., 2020) leading to several disruptions that have not received scholarly attention.

The AECO sector in Ghana employs 10 per cent of workforce and contributes 30 per cent of the gross domestic product (GDP) (Ghana Statistical Service, 2019). AECO sector in Ghana grew by 5.6 per cent in 2021 and projected to peak at 7.5 per cent in 2023 (Fitch Solutions, 2021). The drivers of Ghana's AECO sector include capital investments in infrastructure and

recovery of global oil prices. However, the Covid-19 pandemic has negatively impacted the output of AECO sector in Ghana. Studies such as Agyekum *et al*. (2021); and Amoah *et al*. (2021) demonstrated the negative impacts of Covid-19 on the Ghanaian construction sector with limited focus on environmental turbulence. Again, King *et al*. (2021); Rehman *et al*. (2021); Aigbavboa *et al*. (2021); Chigara and Moyo (2021); Oey and Lim (2021); Sierra (2021); Olukolajo *et al*. (2021); and Oladimeji (2022) focus on short-term impacts and protocols to reduce the spread of Covid-19 with no focus on environmental turbulence created by the pandemic. This study aims to investigate environmental turbulence in the AECO sector from the context of Covid-19, and recommend resilient mechanisms for future pandemics.

2. Literature Review

2.1 Environmental Turbulence

There are two main types of environmental turbulence, namely technological and market turbulence (Shabbir *et al*., 2021). Environmental turbulence is driven by economic and political volatility, globalisation and rapid technological changes (Khouroh *et al*., 2020). Technological turbulence leads to changes in technology structure, method of production and development of innovative products (Wardi *et al*., 2018). AECO firms in developing countries such as Ghana must improve their resilience against future pandemics by adopting technologies that enable them to operate in turbulent environments.

2.2 COVID-19 and the AECO Sector

Covid-19 is a global threat to the AECO sector because it has led to the suspension of projects, shortage of labour and material, rising unemployment and financial losses (Gamil and Alhagar, 2020; Ayittey *et al*., 2020; Nicola *et al*., 2020; Helm, 2020; Simpeh and Amoah, 2021). The negative impact of Covid-19 on the AECO sector is felt as delays and disruption of supply chain led to closure of project sites (Aigbavboa *et al*., 2021; Bsisu, 2020; and Jallow *et al*., 2020).

Economic decline brought in the wake of the Covid-19 had a negative impact on the AECO sector as the pandemic prolongs. The short-term impact of Covid-19 on the AECO sector include the tendency of clients to freeze funds for projects, low level of cash reserves and huge debts that create liquidity problems (Aigbavboa *et al*., 2021; and Deloitte, 2020). The Covid-19 created disruptions that have the potential to drive environmental turbulence in the AECO

sector. However, investigations on Covid-19 disruptions and environmental turbulence are not many, as shown in Table Ⅰ.

INSERT TABLE Ⅰ HERE

Most of the studies in Table Ⅰ focus on the impacts of Covid-19 pandemic including prevention of its spread without addressing the long-term mechanisms for resilience against environmental turbulence beyond Covid-19.

2.3 Institutional Theory

Institutional theory is useful for establishing formal structures, policies, affiliations, collective action and standard practices in organisations (David *et al*., 2019). Institutional theory allows formal structures in organisations to respond to the environment (Alvesson and Spicer, 2019). The choice of the institutional theory for this study is due to the rapid changes occurring in the AECO sector as a result of the Covid-19 disruptions and the need for resilient mechanisms for survival of organisations.

3. Research Methodology

The study adopted quantitative approach and the positivist philosophical tradition. Survey questionnaires were administered to participants working on AECO projects during the peak of Covid-19. The target population consists of project managers, site engineers, quantity surveyors, contractors and subcontractors shown in Figure 1. The study was cross-sectional and undertaken in Kumasi, which is the second largest city in Ghana with a population of 3.348 million people (Ghana Statistical Service, 2020).

The city of Kumasi comprises Greater Kumasi Metropolis, and five municipal assemblies namely Asokore Mampong Municipal Assembly, Asokwa Municipal Assembly, Oforikrom Municipal Assembly, Old Tafo Municipal Assembly and Suame Municipal Assembly. The assemblies regulate and control infrastructure development in the city through permits. Kumasi is a nodal city with several economic and industrial activities such as manufacturing, automobile repair, food, timber and soap processing. The industrial and economic activities in the city drive the demand for AECO projects such as the construction of malls, supermarkets; and civil projects notably expansion of the Kumasi airport.

A pilot study was undertaken involving ten professionals in the AECO sector in which they suggested revision of the variables used to design the survey questionnaires. The survey questionnaire focused on the profile of respondents, Covid-19 pandemic disruptions; and

resilience mechanisms. The questions were closed-ended in which the nominal scale was used to measure profile of respondents while the Likert scale anchored in 1 = strongly disagree, 2 = disagree; 3 = neither agree nor disagree, 4 = agree and 5 = strongly agree was used to measure Covid-19 disruptions and the resilience mechanisms. Validity and reliability of the Likert scale was determined using the Cronbach alpha test, which gave 0.86 indicating high reliability.

The purposive sampling was adopted to distribute 110 questionnaires to participants using an online tool. 52 questionnaires were returned for analysis with a response rate of 47 per cent. A study by Chigara and Moyo (2021) on the impacts of Covid-19 on construction health and safety involved 51 respondents. The descriptive analyses employed include percentages, weighted mean and standard deviation while the inferential statistical tool used was factor analysis to determine the latent factors within the twenty-four Covid-19 disruptions in this study. Factor analysis is used for data reduction and identification of common factors to provide explanations (Zikmund *et al*., 2013).

4. Analysis and discussion of results

This section of the paper focused on the descriptive and inferential analyses of the results. The descriptive analysis was first undertaken followed by the factor analysis.

4.1 Descriptive analysis

The descriptive analysis of the results focused on respondents' profile, Covid-19 disruptions and resilience mechanisms for turbulent environment. The mechanisms for improving the resilience of AECO against Covid-19 are presented in Table IV of section 4.2.2. The profile of respondents regarding their positions are shown in Figure 1.

INSERT FIGURE 1 HERE

From Figure 1, site engineers constitute the majority of respondents while quantity surveyors are the least represented. The position of participants in their firms is relevant to this study because it enhances the face validity of the results. Previous studies have investigated the relationship between the age of a firm and survival using the life-cycle theory of the firm (Bartelsman *et al*., 2005) to enhance the reliability of results. Figure 2, which demonstrates the age of firms involved in this investigation indicates that most of the respondents work in companies that have existed between 5 and 10 years.

INSERT FIGURE 2 HERE

Also, Figure 2 shows that 17.3 per cent of firms involved in the study are over 20 years and between 16 and 20 years old, respectively. The results on the age of firms demonstrate that firms involved in this study have survived in their business environment.

Sectors of operation forms integral part of respondents' profile; hence, Figure 3 shows that participants' firms have undertaken projects in different areas such as civil infrastructure, construction contracting, real estate and industrial infrastructure.

INSERT FIGURE 3 HERE

Though projects executed by AECO firms contribute to the socio-economic development of Ghana (Asamoah and Decardi-Nelson, 2014), the sector continue to operate in a turbulent environment due to the Covid-19 disruptions.

Weighted mean and standard deviation were used to analysed Covid-19 disruptions in Table Ⅱ, which shows that majority of participants highly ranked Covid-19 as the cause of environmental turbulence in AECO project delivery. This is reflected in the value of weighted mean for Covid-19 disruptions, which are above 3.5 except 'inability of workers to concentrate leading to lack of attention to details' in Table Ⅱ. According to Field (2005), Likert scale ranking with weighted mean values above 3.5 is high. In using, the weighted mean to rank the Covid-19 disruptions in Table Ⅱ. there was a mid-range ranking involving variables coded D11 and D12, which were both ranked at 11th position. Overall, the results in Table Ⅱ implies that the disruptions of the Covid-19 are major drivers of environmental turbulence in the delivery of AECO projects.

INSERT TABLE Ⅱ HERE

The results in Table Ⅱ show that 23 Covid-19 disruptions are major drivers of environmental turbulence in AECO project delivery. For instance. Covid-19 disruptions with weighted mean values above 4.00 indicating the propensity to drive environmental turbulence in AECO sector include adherence to statutory protocols on site that tend to delay operations; increased rate of project plan interruptions; and frequent stoppages of site operations leading to project delays. Though Covid-19 protocols were intended to protect workers from contracting the virus, they tend to slow down the performance of AECO workers leading to disruption of project duration and its extensions.

Additionally, the results in Table II indicate that Covid-19 disruptions such as inadequate timelines for project; worker anxiety; supply chain collapse; and material price inflation

causing budget overrun created environmental turbulence in AECO project delivery. The results further demonstrate that Covid-19 has increased the rate at which project scope changes; and other challenges such as delayed payments leading to the disruption of contractors' cash flows.

In Table II, the variables with weighted mean above 3.5 include additional financial resources required to manage Covid-19 protocols; reduced output due to high levels of stress among employees; price instability hampers budget preparation; and difficult resource allocation demonstrating their potential to create turbulent environment for project delivery. Also, Covid-19 disruptions such as claims for expenses incurred for implementing pandemic protocols; inadequate site labour; time overrun; low level of employee wellbeing; and employees' inability to manage their personal time also have their weighted mean more than 3.5 in Table II suggesting that they have the potential to drive environmental turbulence. Since the inability of employees to concentrate on their work has a weighted mean of 3.44, it implies that respondents do not perceive it as a Covid-19 disruption that leads to environmental turbulence in AECO.

The results in Table II are largely consistent with the findings of Osuizugbo (2021, pp. 42) that classified Covid-19 disturbances as 'project abandonment; delay in construction activities; high cost of construction materials; reduction in working hours; lack of funding; and shortage of workforce.' Likewise, Rubin (2021) found that Covid-19 disturbances such as high rate of contractual disputes, temporary closure of project sites and a reduction in productivity, are consistent with the results in Table II.

4.2 Factor Analysis

Factor analysis is used for data reduction and determination of underlying common factors for the interpretation of results (Samereh *et al*., 2022; Doloi, 2008). In this study, factor analysis was used to summarise and categorised the twenty-four Covid-19 disruptions explored to interpret them using the common factors generated. Ogunsanya *et al*. (2022) used factor analysis to investigate the barriers of procurement in Nigerian construction industry while in Ghana Debrah *et al*. (2022) used it for the analysis of key sustainability contents for green cities development.

The Kaiser-Meyer-Oklin (KMO) of the factor analysis for this study was .73, indicating sampling adequacy. According to Howard and Henderson (2023), a KMO value above 0.60 shows the suitability of sampling adequacy for factor analysis. To ensure the quality of

analysis, the survey questionnaires were administered to participants who have undertaken AECO projects during Covid-19 pandemic to enhance accurate responses from participants. This is consistent with the assertion of Meade and Craig (2012) that researchers must enhance the quality of their data for factor analysis by ensuring participants provide accurate responses. The communalities of the factor analysis in this study were between .5 and .83, indicating the variables explained their common factors. The scree plot in Figure 4 shows the eigenvalues plotted against each component. From component 1 to 6, the eigenvalues were above 1 while there is a drop in the eigenvalues from components 7 to 24 indicating a reduction in total variance.

INSERT FIGURE 4 HERE

Factor loadings show the strength of relationship between a component and its variable. For the purposes of interpretation, factor loadings between -1 and + 1 in which values closer to 1 indicate strong relationship. Four variables have been deleted because their factor loadings are below .5 indicating weak association with their components. The four variables deleted were 'increased interruption of schedules; rapid changes in project scope; Material price inflation causing budget overrun; and delayed payments disrupt contractor's cash flow'.

4.2.1 Factor profile of Covid-19 disruptions driving environmental turbulence

Based on the factor loading of variables in Table Ⅱ, the Covid-19 disruptions underpinning environmental turbulence in AECO are presented in Table Ⅲ under six components.

INSERT TABLE Ⅲ HERE

Table Ⅲ demonstrates the six common factors extracted namely scheduling, performance and productivity, project budget, supply chain, resource allocation and technological and regulatory disruptions. Common factors such as scheduling, performance and productivity and project budget disruptions have variables with high factor loading, indicating a strong relationship, which are further analysed below.

Component 1: Scheduling disruptions

The Covid-19 pandemic has the potential to create disruptions in the scheduling of AECO projects. Table Ⅲ shows six variables loaded onto the common factor scheduling, which represents component 1. Variables with strong connection to component 1 include inadequate timelines (factor loading =.72); worker anxiety (factor loading =.80); increased stoppages (factor loading = .61); and disruption of workflow on site (factor loading = .63). Since these

four variables relating to Covid-19 disruptions have their factor loadings above .60, it suggests that they are major drivers of environmental turbulence in AECO project delivery.

Similarly, extensions for delaying key milestones; and inability of employees to manage time on site have factor loadings of .58 and .54, slightly above.50; hence they are not strongly linked to scheduling disruptions. The challenges of scheduling AECO projects have been investigated by Miralinaghi *et al*. (2021); and Zhang (2021) focusing on road projects, and storage space for material, respectively. Earlier studies before the Covid-19 pandemic largely focused on 'project-related characteristics' of time overrun (Catalão *et al*., 2021, pp. 1) with little attention to schedule disruptions emanating from the Covid-19. The result pertaining to scheduling disruption in Table Ⅲ is consistent with Cho and Staley (2021) who found that the Covid-19 pandemic has caused disruptions in the scheduling of projects. A study by Hansen *et al*. (2023) indicates that professionals must improve schedule management practices to reduce project disputes.

Component 2: Performance and productivity disruptions

Performance and productivity challenges in AECO sector have worsen (Hansen *et al*., 2023) due to the emergence of Covid-19 pandemic. Component 2 in Table Ⅲ shows performance and productivity disruptions caused by Covid-19. The four variables strongly associated with performance and productivity component in Table Ⅲ include increased employee stress reduced output (factor loading = .78); poor employee well-being (factor loading =.70); inability of workers to concentrate (factor loading = .63); and social distancing reduces the performance of professionals (factor loading = .64). This suggests that the four variables in component 2 disrupt performance and productivity in AECO projects delivery during Covid-19. In this study, the four variables linked to the performance and productivity are consistent with the finding of Olarewaju and Ajeyalemi (2023) demonstrating that the variables in component 2 create disruptions that drive environmental turbulence in AECO sector.

Ghana's GDP has declined since the emergence of the Covid-19 culminating into low productivity and performance in the AECO sector. However, the AECO sector prior to the pandemic has contributed significantly to the GDP of Ghana. Ghana's GDP contracted by 3.2 percent and 1 percent in the second and third quarters of 2020, respectively (World Bank, 2021) due to Covid-19 disruptions. The disruptions linked to component 2 such as poor employee well-being; increased employee stress reduced output; and inability of workers to concentrate are consistent with Dubey *et al's*. (2020) findings that Covid-19 pandemic causes unintentional

psychological consequences that affects workers' performance and output. The result pertaining to component 2 implies that managers in the AECO sector must develop strategies for enhancing the performance and productivity of employees during the delivery of AECO projects in turbulent environments.

Component 3: Project budget disruptions

The three variables loaded on to component 3 have factor loading above 0.70, suggesting that they are strongly connected to project budget disruptions in Table III. The variables categorised as Covid-19 AECO budget disruptions in Table Ⅲ include delays not addressed by contract (factor loading = .71); additional financial resources for implementing Covid-19 protocols (factor loading =.72); and price instability hampers budget preparation (factor loading= .73). Though contingency funds are allocated for AECO projects, the Covid-19 pandemic has prolonged to the extent that such funds are no longer enough to support the implementation of health protocols for the pandemic. Price instability has disrupted budgetary allocation during the Covid-19 pandemic culminating into the disruption of planned cost for AECO projects. A phenomenon that has created turbulent environment for managing project budgets during the pandemic. In addition, Covid-19 pandemic has led to the price volatility of construction materials and equipment in developing countries (Al-Mhdawi *et al*., 2022), which requires frequent revision of project budgets; thus causing delays and unnecessary constraints in AECO project delivery.

Component 4: Supply chain disruption

An efficient supply system is fundamental to the successful delivery of AECO projects during the Covid-19 pandemic and beyond. However, this study has shown that the Covid-19 pandemic has disrupted the AECO supply chain. From Table Ⅲ, two variables are loaded to component 4, which are delay in the acquisition of project logistics and resources; and increasing rate of late deliveries by suppliers to contractors with factor loadings of .65 and .74, respectively. The weighted mean scores of the two variables loaded onto component 4 are above 4.00, indicating a severe disruption.

Delay in acquisition of project logistics and high rate of late deliveries have led to disruption AECO supply chain thereby creating environmental turbulence. Alenezi (2020) also indicated disruptions caused by the Covid-19 pandemic in the procurement of supplies and services, which are consistent with the supply chain disruption in Table Ⅲ. Covid-19 disruptions in

AECO supply chain have the potential to delay project delivery, which will also affect the project budget. The critical role of infrastructure in controlling the spread of pandemics is currently being jeopardised by the supply chain disruption created by Covid-19 in the AECO sector. In addition, the AECO supply chain system does not have enough resilience to resist the uncertainties (Ekanayake *et al*., 2022) created by the Covid-19. To address some of these challenges, it is imperative for project managers in the AECO sector to develop strategies that improve supply chain resilience. Also, AECO firms must be flexible and proactive in developing resilient supply chain strategies to deal with the disruptions caused by the pandemic. Studies such as Sutterby *et al*. (2023); and Remko (2020) highlighted the need for resilient supply chain due to the catastrophic and long-lasting nature of the Covid-19 pandemic.

Component 5: Resource allocation disruption

The result in Table Ⅲ shows that two variables are loaded onto component 5, which are difficult resource allocation; and inadequate labour on site with factor loadings of .66 and .55, respectively. Similarly, these two variables loaded to component 5 have weighted mean of 3.77 and 3.73 above the 3.5 threshold suggested by Field (2005). Disruptions create uncertainties with negative effects on the allocation of resources for AECO projects. Component 5 in Table Ⅲ shows Covid-19 pandemic has disrupted and rapidly changed the allocation of resources such as labour, finance, equipment and technology for AECO projects. The difficulty of allocating human resources in the AECO sector during the Covid-19 pandemic has been highlighted in existing studies. For instance, Zhong *et al*. (2021) found that Covid-19 has disrupted human resource management across all sectors globally. The AECO is one of the sectors hardest hit by Covid-19 pandemic due to the itinerant nature of its labour force and restrictions on movement.

Component 6: Technological and regulatory disruptions

According to Dearstyne (2012), technological and legal changes; and diminishing resources create environmental turbulence in organisations. Component 6 in Table Ⅲ focuses on the technological and regulatory disruptions that drive environmental turbulence in AECO project delivery during the Covid-19 pandemic. The variables linked to component 6 include adherence to Covid-19 protocols delaying completion of tasks for AECO projects (factor loading = .60); and adoption of new technologies, which initially slow down project delivery (factor loading = .53). The cascading effects of Covid-19 pandemic has made organisations to

demand for tailor-made technologies (Durst *et al*., 2023). Thus, it is necessary for AECO firms to seriously consider the adoption of emerging technologies such as drones, virtual reality, and artificial intelligence, internet of things, blockchain, and cloud computing for the delivery of projects in turbulent environment. However, the adoption of new technologies requires the redesign of internal operations of organisations (Mathivathanan *et al*., 2021).

4.2.2 Mechanisms for improving the resilience of AECO sector against pandemics and beyond

Resilience is the ability to respond to socio-economic and environmental shocks (Wilkinson and Osmond, 2018). The threats posed by Covid-19 has ignited the need to focus on resilience and its associated benefits (Nassereddine *et al*., 2023; and Baron and Cherenet, 2018). Resilience against Covid-19 disruptions and future pandemics is fundamental for the successful delivery of AECO projects in turbulent environment. The results in Table Ⅳ show six mechanisms for improving AECO sector.

INSERT TABLE Ⅳ HERE

Table Ⅳ consists of six mechanisms, which AECO firms must adopt to enhance their resilience against environmental turbulence driven by Covid-19 disruptions. The mechanisms are in Table Ⅳ will drive the key components of institutional theory such as affiliations, collaboration, partnership and promoting collective action among project teams to enhance their capacity for effective project delivery in turbulent environment. Thus, integrating the components of the institutional theory into the implementation of the mechanisms in Table Ⅳ improves the resilience of AECO firms. AECO firms need to strengthen formal organisational structures that drive investment in digitisation and new innovations to optimise the use of social media tools in turbulent project environment. Additionally, organisational policies that promote the mechanisms in Table Ⅳ must be embedded in the formal structures of AECO firms to enable them to easily apply the mechanism during project delivery. The implementation of the mechanisms in Table Ⅳ leads to collaboration, and virtual delivery of projects at different geographical locations.

The result in Table Ⅳ support the findings of Oey and Lim (2021) that highlighted key areas that AECO firms must invest to enhance their resilience in turbulent environment. Similarly, Nassereddine *et al*. (2023) proposed eleven key areas for resilience in which those closely related to this study are collaborative contracting methods, remote working, integrated design

management using BIM, reversible building design, augmented reality, automation and 3D printing and lean construction. The results in Table IV requires incremental implementation of BIM technologies; digitisation; and redesign of organisational social media platforms are consistent with the findings of Nassereddine *et al*. (2023). The result of this paper regarding the use of BIM to enhance the resilience of AECO sector against Covid-19 disruption is consistent with the result of Wang *et al*. (2023). BIM has the potential to strengthen the resilience of the AECO sector, as Idrissi *et al*. (2022) indicated in their study that BIM has a swift uptake globally.

The adoption of BIM technologies will address the challenges posed by the paper-based approach to managing projects in developing countries. However, Atkinson *et al*. (2022) noted that the rapid evolution of paper-based approach into a digital environment creates uncertainties and disruptions. BIM technologies mitigates some of the challenges of AECO indicated in Asiedu and Ameyaw (2021, pp. 831) as 'poor planning, change orders, lack of coordination', which tend to delay the AECO projects leading to time and cost overruns. The readiness of the AECO sector for digital technologies notably BIM is crucial now as potential pandemics will emerge in the future; and 'competitive advantage over economic and environmental benefits' will be crucial (Lou *et al*., 2022, pp. 301).

The mechanisms for enhancing the resilience of AECO sector in this study implies that there is a need for practitioners in the sector to consider collaborations that improve their capacity for effective delivery of project during future pandemics. The resilience mechanisms proposed is supported by the post Covid-19 framework proposed by Gartoumi *et al*. (2022), which partly focused on promotion of technology; collaborative practices; social measures and remote working; and compliance of construction practices with health and safety measures.

5. Conclusion

This study categorises twenty-four Covid-19 disruptions driving environmental turbulence in AECO project delivery into scheduling, performance and productivity, project budget, supply chain, resource allocation and technological and regulatory disruptions. AECO firms must develop their resilience against environmental turbulence by adopting digital technologies, and redesign of organisational structures to address future disruptions caused by pandemics. The implementation of policies to drive the mechanisms for resilience in environmental turbulence driven by Covid-19 is imperative for AECO firms if they intend to survive future pandemics. This paper has the potential to improve professionals' understanding of disruptions driven by pandemics during AECO project delivery. It is important that project stakeholders formulate

policies to drive the implementation of the resilience mechanisms indicated in this paper to enable AECO firms to survive in turbulent environment. This implies that project managers, clients, consultants, public sector agencies and communities must be aware of the challenges that environmental turbulence pose to AECO projects.

The study is quantitative in nature; hence, limited in terms of using qualitative approach to explore the issues. Therefore, a future study focusing on the use of the qualitative approach for an in-depth investigation of the six categories of Covid-19 disruptions identified will provide more insight on environmental turbulence in AECO project space. Future research must address scenario and long range planning for pandemics with much focus on scheduling, performance of human resource and productivity in turbulent environment.

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Table Ⅰ: Existing studies on the impacts of Covid-19 on the construction industry

Authors	Focus of study
Rehman *et al*. (2021)	Impacts of COVID-19 on construction project performance
King *et al*. (2021)	Critical analysis of Covid-19 impacts on architectural, engineering, and construction organisations
Agyekum *et al*. (2021)	Impacts of Covid-19 on construction firms
Amoah *et al*. (2021)	Impacts of Covid-19 on small construction firms
Aigbavboa *et al*. (2021)	Impacts of Covid-19 on unprepared construction industry
Chigara and Moyo (2021)	Impacts of Covid-19 on construction health and safety
Sierra (2021)	Impacts of Covid-19 on the construction phase of projects
Oey and Lim (2021)	Action plans for addressing the impacts of Covid-19
Olukolajo *et al*. (2021)	Covid-19 protocol compliance among construction site workers
Oladimeji (2022)	Influence of Covid-19 on the viability of local construction firms

Table Ⅱ: Covid-19 pandemic disruptions driving environmental turbulence in AEC project delivery

Code	Drivers of turbulence due to Covid-19 pandemic disruptions	Weighted Mean	Std. Deviation	Ranking
D1	Statutory regulations for protocols hamper delivery	4.48	0.75	1
D2	Increased interruption of schedules	4.46	0.67	2
D3	Increased stoppages	4.27	0.77	3
D4	Inadequate timelines	4.25	0.95	4
D5	Worker anxiety	4.17	0.90	5
D6	Supply chain collapse delays resource acquisition	4.15	0.96	6
D7	Delays not addressed by contract	4.15	0.92	6
D8	Material price inflation causing budget overrun	4.13	0.84	8
D9	Rapid changes in project scope	4.08	0.71	9
D10	Delayed payments disrupt contractor's cashflow	4.04	0.95	10
D11	Disruption of employee performance	4.02	1.04	11
D12	Increased late deliveries	4.02	1.00	11
D13	Workflow disruption	4.00	1.01	13
D14	Additional financial resources required for pandemic protocols	3.96	1.15	14
D15	Increased employee stress reduced output	3.87	1.12	15
D16	Price instability hampers budget preparation	3.83	0.99	16
D17	Difficult resource allocation	3.77	1.11	17
D18	Inability to claim expenses for pandemic protocols during interim payments	3.75	1.15	18
D19	Inadequate labour on site	3.73	1.14	19
D20	Extensions for delaying key milestones	3.67	1.18	20
D21	Poor employee well-being	3.65	1.03	21
D22	Inability of employees to manage time on site	3.58	1.09	22
D23	Adoption of new technologies initially slows down work	3.52	1.18	23
D24	Inability of workers to concentrate	3.44	1.19	24

Table Ⅲ: Factor profile of covid-19 disruptions driving environmental turbulence in AEC projects delivery space

Code	Components and variables	Factor Loading
	Component 1: Scheduling disruptions	
D3	Increased stoppages	.612
D4	Inadequate timelines	.720
D5	Worker anxiety	.796
D13	Workflow disruption	.630
D20	Extensions for delaying key milestones	.583
D22	Inability of employees to manage time on site	.542
	Component 2: Performance and productivity disruptions	
D11	Disruption of employee performance	.643
D15	Increased employee stress reduced output	.783
D21	Poor employee well-being	.703
D24	Inability of workers to concentrate	.628
	Component 3: Project budget disruptions	
D6	Supply chain collapse delays resource acquisition	.708
D8	Material price inflation causing budget overrun	.716
D10	Delayed payments disrupt contractor's cashflow	.734
D14	Additional financial resources required for pandemic protocols	.509
	Component 4: Supply chain disruption	
D6	Supply chain collapse delays resource acquisition	.654
D11	Disruption of employee performance	.742
	Component 5: Resource allocation disruption	
D17	Difficult resource allocation	.663
D19	Inadequate labour on site	.550
	Component 6: Technological and regulatory disruptions	
D1	Statutory regulations for protocols hamper delivery	.600
D23	Adoption of new technologies initially slows down work	.529

Table Ⅳ: Mechanisms for building the resilience of AEC firms against future global pandemics

Mechanisms for addressing turbulence created by the Covid-19 pandemic	Weighted mean	Std. dev.	Ranking
1. Redesign of organisational social media platforms (skype, zoom)	4.23	1.148	2nd
2. Incremental implementation of Building Information Modelling technologies to drive teamwork	4.25	.738	1st
3. Digitisation of site operations and tasks through the adoption of robots	3.42	1.433	6th
4. Investment in emerging technologies for site management instead of using existing manual processes.	3.88	1.132	5th
5. Developing organisational policies that scrutinise accessibility to sites	3.94	1.211	4th
6. Adopt a holistic approach that enhances system integration through resource management solutions, labour tracking, field reporting and information gathering.	4.13	.841	3rd

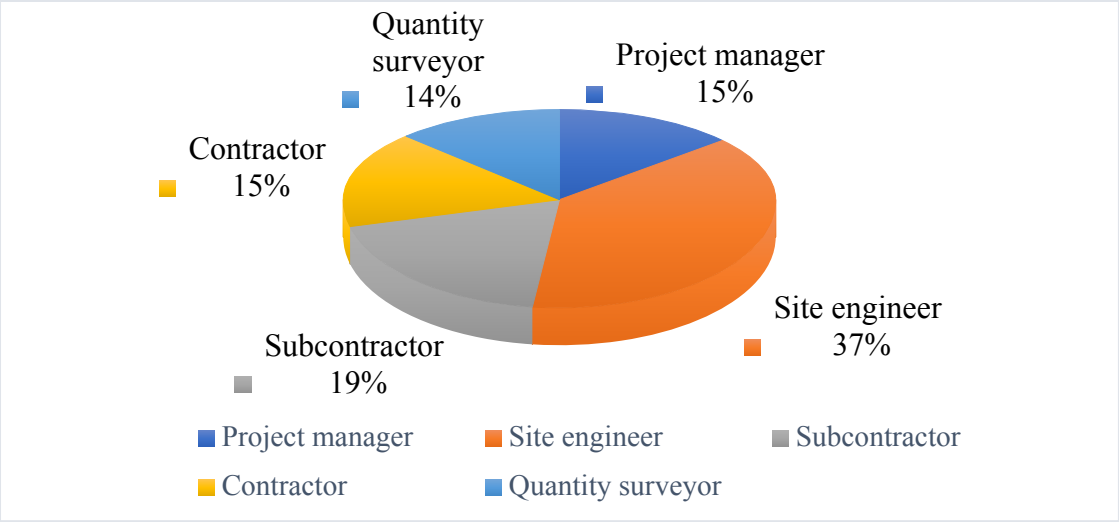

Figure 1: Position of respondents in their firms

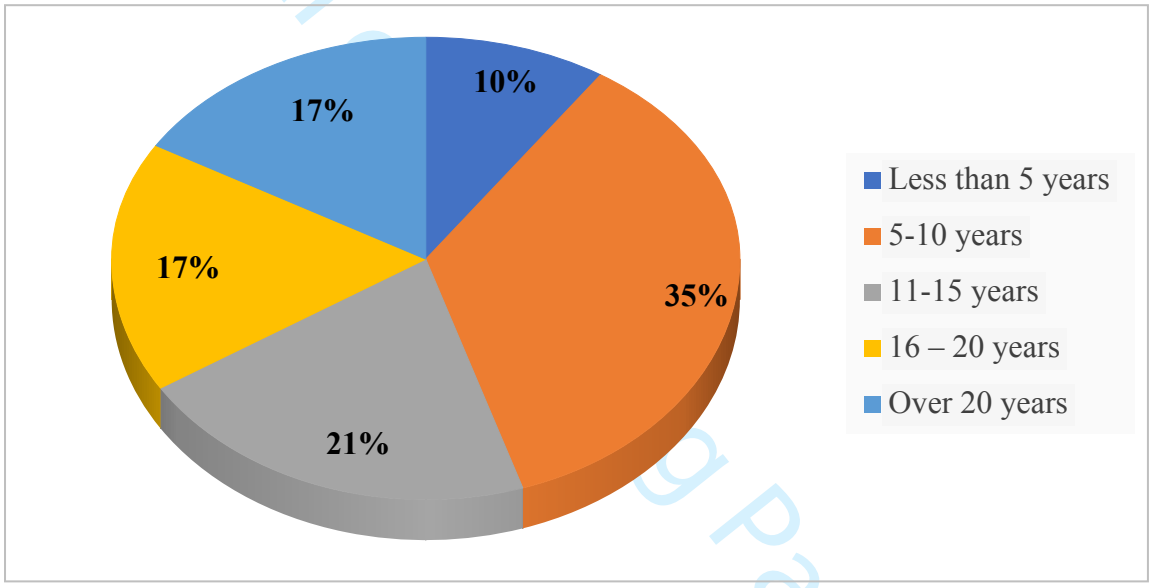

Figure 2: Age of firms

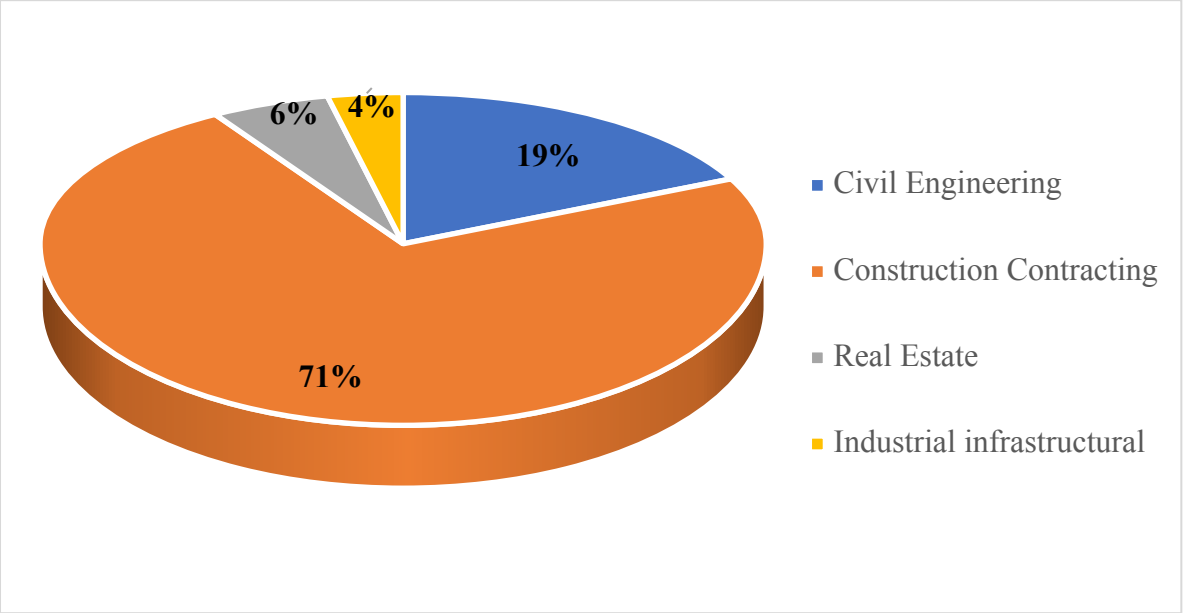

Figure 3: Sectors of operation

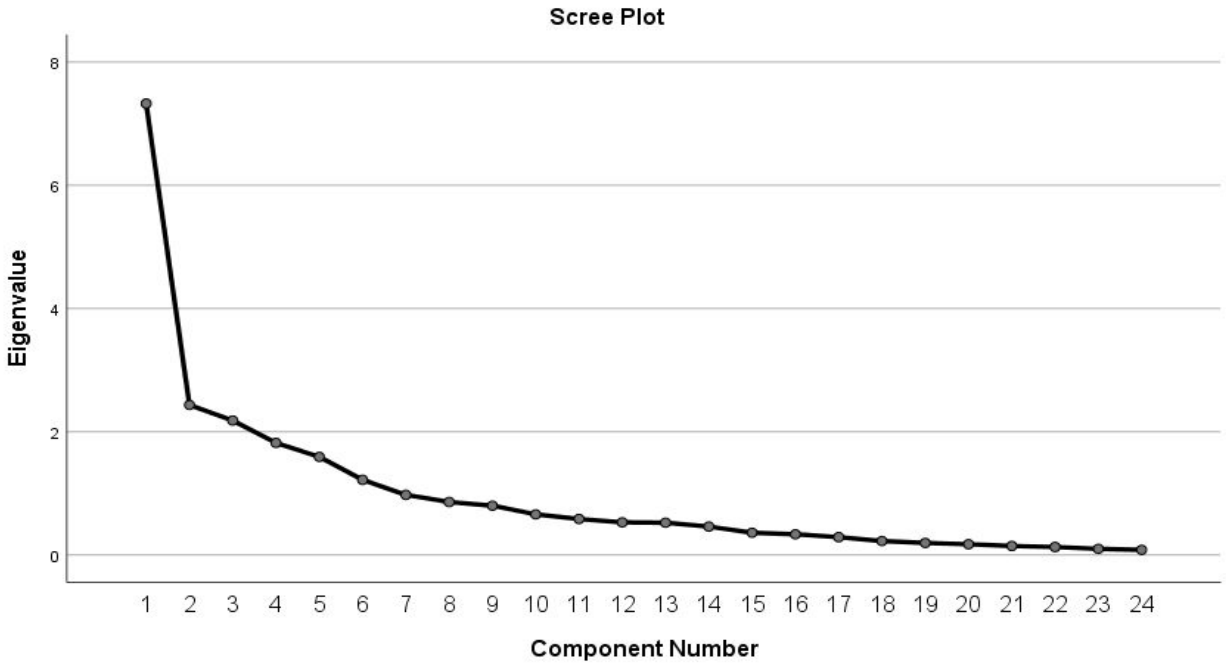

Figure 4: Scree plot