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The Ripple Effects of COVID-19 on South Africa's Building and Construction Industry: Workforce Reduction and Project Delays

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Abstract

This study examines the impact of workforce reduction on project completion times in the South African construction industry during the COVID-19 pandemic. Adopting a positivist research philosophy with a quantitative design, the study utilized an online survey targeting CIDB-registered contractors, yielding 62 responses. Despite minimal overall workforce reductions, the loss of skilled labor significantly impeded project progress, primarily due to quarantine protocols. The research applies the Adaptive Chaos Management Theory in Construction (ACMTC), highlighting non-linear dynamics and the critical role of skilled labor. Findings reveal substantial project delays linked to workforce shortages, underscoring the need for flexible workforce strategies and robust health protocols. Recommendations for the industry include adopting multi-skilling, enhancing health measures, and investing in technology. Policy suggestions advocate for pandemic-specific construction guidelines and incentives for technological advancements. Academia is urged to further explore workforce management strategies and the integration of technology in crisis contexts. This study contributes to both theoretical understanding and practical applications, providing a framework for resilience in construction project management amid global disruptions.

Keywords: Construction industry, COVID-19, Project delays, Quarantine impact, Skilled workforce reduction, South Africa.

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Highlights

- COVID-19 interventions significantly reduce workforce in South African construction.

- Quarantine measures identified as leading cause of workforce loss.
- Reduction of skilled workers critically delays project completion timelines.
- Study underscores need for strategic pandemic recovery plans in construction.
- Provides a comprehensive framework to address long-term impacts of pandemics in construction.

Abbreviations

ACMTC - Adaptive Chaos Management Theory in Construction, CIDB - Construction Industry Development Board, COVID-19 - Coronavirus Disease 2019, H1N1 - Hemagglutinin 1 Neuraminidase 1, SARS-CoV-2 - Severe Acute Respiratory Syndrome Coronavirus 2, SPSS - Statistical Package for Social Sciences.

1. Introduction

1.1 Pandemics' Long-Term Impact on Humanity and Construction

Throughout history, outbreaks of contagious diseases have had substantial and lasting effects on humanity, significantly impacting the construction sector [1–4]. These outbreaks have profoundly influenced the economic, political, and social dimensions of human civilization, with their effects persisting for centuries [5–8]. Notable examples include the 1918 H1N1 (Spanish Flu), the 2009 A/H1N1 (Swine Flu), and the 2019 COVID-19 pandemic caused by SARS-CoV-2 [9–13]. The impact of such diseases on global activities, including construction, has prompted event studies like this one [10,12,13]. Event studies allow researchers to examine the effects of specific events at particular times, as demonstrated in the construction industry during the peak of COVID-19 [9,13,14].

1.2 COVID-19's Effects on Construction Delays and Workforce Reduction

COVID-19 exacerbated existing delays within the construction industry, significantly affecting project completion times [15–18]. Restrictions on movement and interpersonal interactions, primarily enforced through lockdown measures of varying restrictiveness, disrupted the execution of construction projects, leading to missed milestones and deadlines [13,19–23]. These disruptions were anticipated to affect project turnaround times, causing job losses in the short, medium, and long term [21,24,25]. Additionally, the pandemic was expected to result in revenue losses, economic downturns, and business disruptions within the South African building and construction industry [26,27]. Consequently, workforce reductions led to many construction projects failing to meet their scheduled milestones. However, due to the novelty of the pandemic, a comprehensive theory explaining these observed phenomena appears to be absent from existing epistemological frameworks.

1.3 Research Gap: Exploring COVID-19's Long-Term Impact on Construction

Despite extensive research documenting the impacts of pandemics on various industries, the specific effects of COVID-19 on the construction sector, particularly in South Africa, remain underexplored [28–34]. Previous studies have primarily focused on immediate operational disruptions and broad economic impacts, neglecting the intricate dynamics of workforce reduction and its consequential effects on project completion times within the construction industry [28,35–42]. This oversight is significant given the critical role of skilled labor in maintaining project timelines and ensuring economic stability within the sector; with existing literature and frameworks often overlooking the nuanced interplay between workforce availability and project management strategies during unprecedented global

health crises, often lacking theoretical foresight to provide a foundation for study's over a longitudinal period [43–47]. There is a scarcity of theoretical frameworks applied to empirically analyze these dynamics. This gap underscores the need for detailed empirical investigations to bridge these knowledge disparities and enhance the theoretical understanding of crisis management in construction. A study with comprehensive insights into how minor reductions in skilled labor can lead to disproportionately large delays in project completions is lacking in the body of knowledge, and thus, a study is required to offer a deeper understanding of the sector's vulnerabilities and resilience strategies in the face of pandemics, especially from a theoretical perspective. Addressing this knowledge gap necessitates a re-evaluation of current management frameworks and the development of more resilient strategies capable of withstanding such disruptions.

1.4 Problem Statement: Skilled Labor's Role in Pandemic Construction Delays

The COVID-19 pandemic has unveiled significant challenges within the construction industry, particularly highlighting the critical dependency on skilled labor for maintaining project timelines [48–50]. Despite recognizing labor as a pivotal element in construction management, there is a paucity of focused research on how reductions in the workforce, particularly skilled labor, influence project completion during health crises. This issue is exacerbated in environments like South Africa, where the construction sector plays a vital role in the economy but is highly susceptible to external disruptions such as global pandemics [45]. Traditional project management strategies may not be adequately equipped to handle the abrupt and unpredictable disruptions caused by pandemics [51–54]. Existing models and theories often fail to account for the non-linear impacts of small changes in workforce availability on project outcomes. Investigating the specific impacts of COVID-19-induced workforce reductions on the completion times of construction projects in South Africa is required.

1.5 Aim of the Study: Assessing Workforce Reduction Impacts in Construction

The primary aim of this study is to thoroughly investigate the specific effects of workforce reduction on project turnaround times within the South African construction industry during the COVID-19 pandemic. This research seeks to quantify the impact of losing skilled labor on the completion schedules of construction projects and to examine the efficacy of existing management strategies in mitigating these effects. Additionally, the study aims to apply the Adaptive Chaos Management Theory in Construction (ACMTC), a theory for which it develops to explain the observed phenomenon, to evaluate whether this theoretical framework can effectively interpret the complex dynamics observed during the pandemic. By doing so, the research intends to contribute to both theoretical and practical advancements in construction project management by developing a deeper understanding of how to manage and adapt to the disruptions caused by global health crises efficiently. Ultimately, the study's goal is to provide actionable insights and robust strategies that can help stakeholders in the construction industry prepare for and respond to similar challenges in the future, thereby enhancing the resilience and sustainability of construction practices in volatile environments.

1.6 Main Research Question: Skilled Labor Reduction and Management Theory

MRQ: How does the reduction of skilled labor due to COVID-19 impact project turnaround times in the South African construction industry, and in what ways can the Adaptive Chaos Management Theory in Construction (ACMTC) be applied to improve resilience and effectiveness in project management practices during global crises?

1.7 Research Sub-Questions: Labor Reduction, Management Strategies, and Theory

To address the main research question comprehensively, the study is guided by the following three interrelated sub-questions, each targeting specific facets of the study's findings:

1.7.1 SQ1: What is the extent of the impact of skilled labor reduction on the completion times of construction projects during the COVID-19 pandemic in South Africa?

1.7.2 SQ2: How do existing project management strategies and practices in the South African construction industry adapt to the challenges posed by sudden reductions in workforce during a global crisis?

1.7.3 SQ3: In what ways can the Adaptive Chaos Management Theory in Construction (ACMTC) be integrated into project management practices to enhance resilience and adaptability in response to workforce disruptions during pandemics?

1.8 Research Objectives: Labor Impact, Evaluating Strategies, and Applying ACMTC

To thoroughly explore the main research question and its sub-questions, the study is structured around the following three research objectives:

1.8.1 RO1: To determine the specific impacts of skilled labor reductions on project turnaround times in the South African construction industry during the COVID-19 pandemic.

1.8.2 RO2: To evaluate the effectiveness of existing project management strategies in the construction industry during the workforce disruptions caused by the COVID-19 pandemic.

1.8.3 RO3: To explore the application of the Adaptive Chaos Management Theory in Construction (ACMTC) to enhance project management practices for better handling of workforce disruptions during global crises.

1.9 Research Assumptions: Workforce Impact and Management Strategies

For the effective execution and interpretation of the study, it is crucial to establish assumptions that underpin the research framework. The three assumptions relevant to this study include:

1.9.1 Workforce Reductions Directly Impact Project Turnaround Times

The study assumes that reductions in the skilled workforce, due to COVID-19-related factors such as illness, quarantine, or preventative measures, have a direct and measurable impact on the completion times of construction projects. This assumption is based on the notion that skilled labor is critical to maintaining project timelines and that any reduction would naturally lead to delays.

1.9.2 Existing Project Management Strategies are Not Fully Equipped to Handle Pandemic-Induced Disruptions

It is assumed that current project management strategies within the South African construction industry are not fully prepared or adequately flexible to manage the disruptions caused by sudden and significant workforce reductions during a pandemic. This assumption suggests a gap in current management practices that could be addressed through the application of new theoretical approaches like ACMTC.

1.9.3 The Adaptive Chaos Management Theory in Construction (ACMTC) is Applicable and Useful in Addressing Construction Project Disruptions

This assumption posits that the principles of ACMTC are relevant and can be effectively applied to the construction industry to improve management practices and outcomes in the face of chaos induced by pandemics. It assumes that the theory provides a viable framework for enhancing resilience and adaptability in project management strategies during such unprecedented disruptions.

1.10 Research Hypotheses: Skilled Labor, Strategy Efficacy, and Theory Application

Formulating research hypotheses is crucial for testing the theoretical assumptions and providing empirical validation within the study. Based on the research objectives, three hypotheses are tailored to guide and test the outcomes of the investigation [55]:

1.10.1 H1: There is a significant negative impact of skilled labor reduction on construction project turnaround times during the COVID-19 pandemic in South Africa. This hypothesis posits that reductions in skilled labor due to COVID-19 will statistically correlate with an increase in project completion times, evidencing a direct detrimental effect on project schedules.

1.10.2 H2: Current project management strategies in the South African construction industry are inadequate in fully addressing the disruptions caused by workforce reductions during the COVID-19 pandemic. This hypothesis suggests that existing project management practices, when evaluated against the challenges imposed by the pandemic, will show limitations in effectiveness, indicating a need for improved strategies or methodologies.

1.10.3 H3: Implementing principles from the Adaptive Chaos Management Theory in Construction (ACMTC) significantly improves the management of construction projects during workforce disruptions caused by pandemics. This hypothesis asserts that the application of ACMTC to project management under pandemic conditions will lead to better management outcomes, demonstrating the theory's practical utility and effectiveness in enhancing project resilience and adaptability.

2. Literature Review

2.1 Introduction: Exploring COVID-19's Impact on South Africa's Construction Delays

2.1.1 COVID-19 exacerbated pre-existing delays in the construction industry, prompting the built environment to adopt measures to mitigate further project completion delays [56–62]. Despite the ongoing uncertainties surrounding COVID-19, it is crucial to investigate its impact on South Africa's construction sector, especially concerning project turnaround times [45,63]. This literature review aims to elucidate the effect of workforce reduction on project completion timelines, evaluating the extent of its influence on construction projects. The review relied on articles from reputable journals and databases, focusing on COVID-19's implications for the construction industry. Selection criteria involved keyword identification and thorough examination of abstracts, findings, and conclusions, ensuring articles' relevance to construction and project management. Preference was given to peer-reviewed sources. The review predominantly features studies published within the last five years, reflecting the novelty of COVID-19 as a global challenge. The selection was guided by the publication date and relevance, with a focus on recent and pertinent literature [64].

2.2 Theoretical Literature Review

2.2.1 Applying Chaos Theory to Construction Project Management Amid Pandemics

In management, various theories such as Administrative Management Theory, Contingency Theory, Team Building Management Theory, Theory X and Y, Quantitative Approach, and Chaos Theory are applied [65–70]. These theories underscore the theme of change and how it can be effectively managed. The research problem of this study was examined through the Chaos Theory perspective, which elucidates the fundamental mechanisms of chaos, including its manifestation in pandemics like COVID-19 and other epidemics. Chaos Theory is pivotal for articulating the complexities of Construction Project Management, given its focus on the inherent unpredictability in budgeting, profitability, linear analysis, and strategic planning [54,71]. At its essence, Chaos Theory posits that any system is perpetually susceptible to chaos, encompassing wide-ranging phenomena from pandemics and epidemics to shifts in the economy, climate variations, and demographic changes [54,70–76].

2.2.2 Chaos Theory's Insight on COVID-19 Disruptions in Construction

The advent of COVID-19 induced significant shifts in the global economy and population, directly impacting the daily operations of the construction industry [77–84]. Consequently, this study adopts Chaos Theory to elucidate the pervasive disorder COVID-19 has introduced into the construction sector. Chaos Theory, with its focus on non-linear dynamics, challenges traditional models that aim to explain phenomena through regularity, equilibrium, stability, and predictability [54,71–76,85]. It asserts that outcomes are not always directly proportional to their inputs , illustrating how minor alterations can result in substantial system-wide changes, a principle often observed in intervention research [75]. Despite the general assumption that interventions should be carefully evaluated for their fit and potential consequences prior to implementation, the chaotic nature of events like the COVID-19 pandemic frequently overrides such considerations [54,71,86]. A purview into theory, therefore, examines the effects of interventions devised to mitigate project delays during the peak of the COVID-19 crisis in South Africa, using Chaos Theory to analyse the interplay between these interventions and their impacts on project timelines and construction delays during the pandemic. This study builds upon and expands Chaos Theory by applying its principles to the construction industry's response to the COVID-19 pandemic. By examining the non-linear dynamics and unpredictability inherent in crisis situations, the research highlights how even minor disruptions, such as the loss of a small number of skilled workers, can have disproportionately large impacts on project timelines. This application of Chaos Theory underscores the "butterfly effect," where small initial changes lead to significant outcomes, and emphasizes the need for adaptable and resilient management strategies [54,70–78,85,85,87–89]. Through the development and validation of the Adaptive Chaos Management Theory in Construction (ACMTC), the study not only reinforces the relevance of Chaos Theory in understanding complex, dynamic systems but also provides practical insights and a framework for managing construction projects amid global disruptions, thereby expanding the theoretical and practical applications of Chaos Theory in the built environment.

2.3 Theoretical Framework: Adaptive Chaos Management Theory in Construction

The theoretical framework for this study, derived from Chaos Theory, encapsulates the complex interplay between systemic disruptions and the construction industry's response to the COVID-19 pandemic. The following four tenets provide a foundation for

understanding the dynamics at play and tests in reality the following tenets to formalize the Adaptive Chaos Management Theory in Construction (ACMTC) [55]:

2.3.1 Non-Linear Dynamics and Unpredictability

At the heart of Chaos Theory is the acknowledgment that systems behave in non-linear ways, where outcomes are not directly proportional to inputs. This tenet is crucial for analysing how seemingly minor disruptions caused by COVID-19 led to significant, unforeseeable impacts on construction project timelines and workforce dynamics. It underscores the importance of expecting and planning for unpredictable shifts in project management and operational strategies [54,70–73,75,76].

2.3.2 Sensitivity to Initial Conditions

Often referred to as the "butterfly effect," this principle suggests that small changes in a system's initial conditions can lead to vastly different outcomes. Applied to the construction industry during the pandemic, this tenet highlights how initial responses to the outbreak—ranging from workforce reduction to the implementation of safety measures—had profound, sometimes unpredictable effects on project completion and economic stability [54,70–78,85,85,87–89]. The "butterfly effect" of initial conditions—such as early responses to the pandemic—has had profound and varied impacts on project outcomes [54,70–78,85,85,87–89]. This sensitivity has manifested in the way small decisions made at the onset of the pandemic determined the later success or failure of managing project delays and maintaining economic stability. The pandemic has underscored the necessity for adaptability and resilience as described in this tenet. The construction industry's response to COVID-19, through the development of flexible project management practices and resilient operational strategies, has exemplified how systems can adjust and evolve in response to external shocks.

2.3.3 Adaptability and Resilience in the Face of Chaos

Drawing from Chaos Theory, this tenet emphasizes the capacity for systems to adapt and evolve in response to chaotic conditions. For the construction industry, it suggests that developing flexible project management practices and resilient operational strategies is essential for navigating the uncertainties introduced by pandemics and other disruptive events [75,88–95]. This adaptability has been key to sustaining operations and minimizing disruptions during the pandemic. The potential for new, adaptive structures to emerge from chaotic conditions has been vividly illustrated in the construction industry's evolution throughout the pandemic. Innovations in project management, labor practices, and safety protocols have begun to reshape the industry, pointing to a future where enhanced efficiency and resilience could become the norm. This tenet confirms that chaos, while disruptive, can also be a catalyst for significant positive transformation within the industry.

2.3.4 Emergence of New Order from Chaos

Chaos Theory posits that within chaotic systems, there exists the potential for new, more adaptive structures and patterns to emerge. This tenet is applied to the study by exploring how the construction industry might evolve post-pandemic, identifying opportunities for innovation in project management, labor practices, and safety protocols that could lead to improved efficiency and resilience against future disruptions [54,70,71,73,74,74,75].

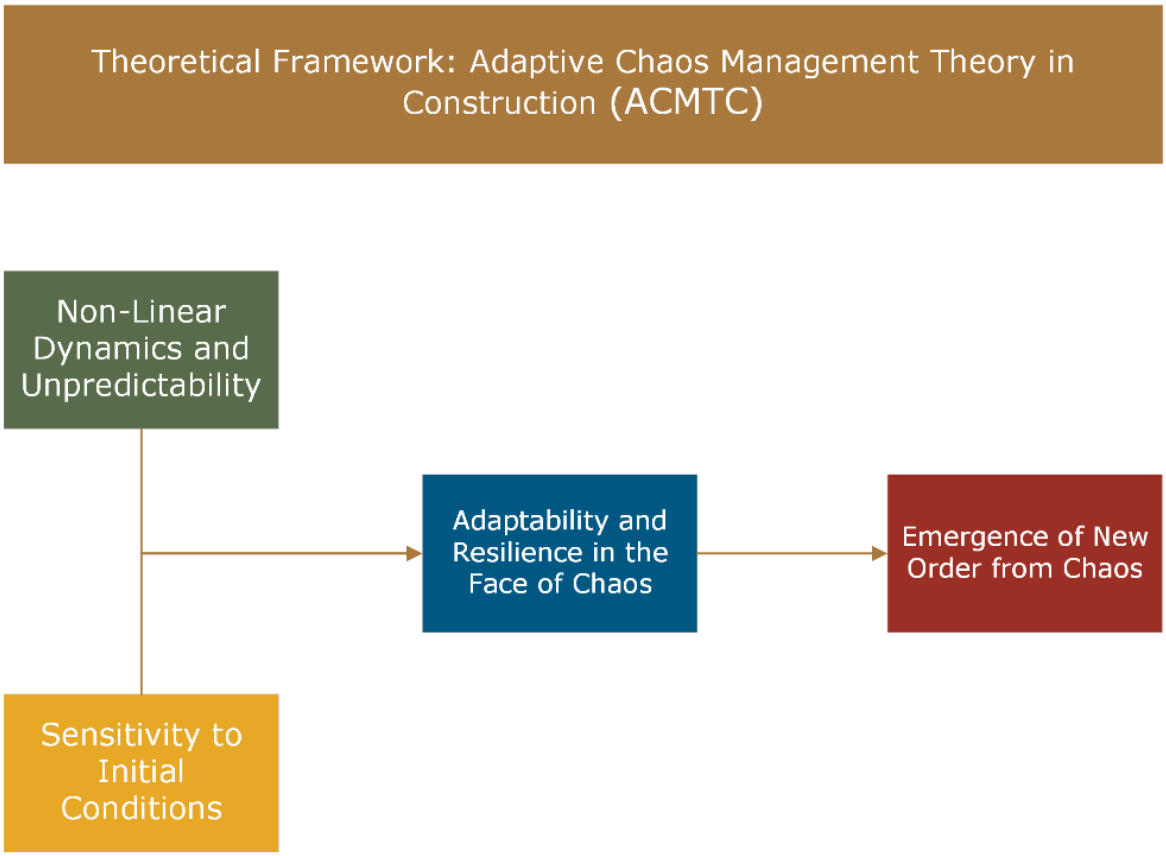

Figure 1: Theoretical Framework for Adaptive Chaos Management Theory in Construction (ACMTC)

2.5 Adaptive Chaos Management Theory Validates Construction Project Resilience

The synthesis of this study through the lens of the newly conceptualized Adaptive Chaos Management Theory in Construction (ACMTC) underscores a significant advancement in understanding how unforeseen crises like the COVID-19 pandemic impact construction project management. Drawing from the foundational principles of Chaos Theory, this research intricately analyzes the non-linear dynamics and unpredictability that pandemics inject into the construction sector, providing a novel lens to observe phenomena in project management. The findings validate the theory by demonstrating how even minimal reductions in skilled workforce—prompted by quarantine and health safety measures—can drastically impede project milestones and timelines. Such disruptions, though seemingly minor, catalyze significant ripple effects across project outcomes, affirming the "butterfly effect" described in Chaos Theory [54,70–78,85,85,87–89].

2.7 Empirical Literature Review

Chaos and the Reshaped Global Construction Industry

The COVID-19 pandemic has significantly reshaped the landscape of the global construction industry, intensifying existing challenges and necessitating novel interventions to manage unforeseen disruptions [96–103]. This empirical literature review delves into the multifaceted impacts of the pandemic on South Africa's construction sector, examining how the industry has responded to the crisis and the effectiveness of various strategies implemented to ensure continuity and resilience [30,61,77,89,90,92,93,104–106]. By

drawing on a wide range of studies from 2019 to 2024, this review synthesizes insights into the delays experienced, the adaptive measures adopted, and the broader implications of these interventions on project productivity and workforce dynamics. Focusing on South Africa, a region that swiftly enacted strict measures in response to the outbreak, this review explores the direct responses enacted within the construction industry to combat the spread of the virus and mitigate its impacts on project timelines and labor forces [45]. By analyzing empirical data and theoretical perspectives, particularly through the lens of Adaptive Chaos Management Theory, the review addresses the critical need for comprehensive analysis before the implementation of intervention measures and evaluates the real-world effectiveness of such strategies [55,107–109].

In presenting a detailed examination of health-related absenteeism, workforce adjustments, and project management adaptations, this literature review provides a crucial understanding of the pandemic's enduring impact on construction. It highlights the need for strategic foresight, flexibility, and rigorous evaluation of interventions to enhance industry preparedness for future global disruptions. Through this scholarly discourse, the review not only contributes to academic knowledge but also offers practical insights for industry stakeholders aiming to navigate the complexities introduced by COVID-19 and similar crises.

2.7.1 COVID-19's Impact and Response in South Africa's Construction Industry

The COVID-19 pandemic has exacerbated a pre-existing spectrum of challenges within the construction industry's management at all levels [94,110–113]. To deepen understanding of this recent phenomenon, identified late in 2019, a review of literature spanning from 2019 to 2022 was conducted. This review revealed that South Africa responded swiftly to the pandemic by enforcing lockdown measures [45,114,115]. Key issues identified in the literature related to COVID-19's impact on the construction industry include experienced delays and the implementation of interventions to mitigate further delays [79,81,82,94,100,101,105,111]. However, the literature appears to overlook or underemphasize the consequences these interventions have had on the construction sector and continues to have on the construction sector in the long term [45].

2.7.2 South Africa's Construction Industry Adapts to COVID-19 Challenges

According to 18 case studies from various countries across the globe, COVID-19 necessitated varied interventions to mitigate delays in their construction industries [34,39,40,42,44,45,47,48,61,77,79,81,82,94,100,101,111]. The South African construction sector enforced stringent measures to curtail the virus's swift spread, mandating the use of facemasks, gloves, face guards, routine hand sanitization, and daily temperature checks at entry and exit points [15]. Yet scant literature has been published regarding the South African construction industry, the largest on the African continent [116]. Additional precautions included the placement of hazardous bins and the requirement for workers to fill out registers and answer screening questionnaires, all aimed at monitoring and controlling the virus's transmission rate [117]. The majority of South African construction projects adopted guidelines addressing site access, induction processes, management of COVID-19 cases, and social distancing practices [96]. These measures prompted scholarly discussions on the impacts of airborne and respiratory diseases like COVID-19 on construction project productivity. Theoretically, such pandemics necessitate comprehensive analysis and evaluation before implementing measures to mitigate their

effects, given their propensity to induce complex and rapid changes [105]. However, empirical evidence suggests that the analytical phase is often overlooked in practice, especially when initial plans falter [118]. The paradox, shift work, intended to minimize COVID-19 transmission among workers, inadvertently led to project delays due to reduced manpower [119]. This multitude of global evidence from 18 different countries underscores the significance and methodology of the current study, emphasizing its necessity and relevance.

2.7.3 Health Absenteeism and COVID-19 Interventions in Construction Impact

Health-related absenteeism was observed to significantly reduce the workforce, potentially leading to the shutdown of construction projects if prolonged [120–125]. When construction site processes proceed smoothly, projects can still encounter setbacks if issues arise with lower-tier subcontractors and suppliers [31,104,121,126–128]. This study, focusing on workforce reduction, examined the impact of COVID-19 intervention measures on construction project turnaround times, thereby proposing a solution framework. Through the application of Chaos Theory and empirical evidence, it was deduced that the most effective strategy for mitigating the spread of the virus involved early vaccination of workers [129–132]. This approach enabled project managers to predict and manage project timelines amidst the pandemic more accurately. However, the scarcity of detailed information on the outcomes of various interventions to alleviate COVID-19 induced delays underscores the significance of this research.

2.7.4 COVID-19's Global Impact and Management in Construction Industry

The COVID-19 pandemic precipitated unprecedented socio-economic upheavals globally, significantly impacting various industries, including construction [114,133–135]. The pivotal role of adept management in ensuring project success, especially in the face of unforeseen events like the COVID-19 pandemic is scantly studied and is novel to the management sciences [118,133,136–138]. Current reviews highlight a shallow overview of the COVID-19's impact on the construction industry, rather than detailing the delays induced by COVID-19 and explaining it from a phenomenological perspective, most studies present data and do not engage in the theoretical implications pandemics have had and will have in the future, especially from a theoretical perspective [29, 32, 43, 48, 53, 61, 83, 97, 99, 101, 103, 116, 121, 125, 127, 130, 133, 139].

Subsequently, most reviews explore the interventions devised to mitigate these delays. Often lacking the ability to delve into the global response to workforce reduction and the measures adopted on construction sites to counteract the pandemic's effects. Furthermore, the reviews examine the impact of these interventions on project turnaround times, but do not directly inform the research question.

Literature continues to fail to grasp the concept of Chaos Theory in construction, which posits that outcomes are not directly proportional to inputs, this study advises caution in the implementation of interventions, reflecting the unpredictable nature of COVID-19's effects across various sectors, and not only construction [54,71,75,86]. This unpredictability, emblematic of Chaos Theory, suggests that minor changes can have profound systemic impacts. Nevertheless, not all interventions are deemed counterproductive. For instance, shift work social distancing strategies, albeit reducing worker exposure to COVID-19, inadvertently led to project delays due to diminished on-site workforce, highlighting the

need for strategic planning in mitigating the spread of viral infections [36,79,81,119,122,127].

2.8 Adapting Construction Management to Global Pandemics: Insights and Strategies

This empirical literature review has elucidated the extensive and varied impacts of the COVID-19's pandemic on South Africa's construction industry, with particular emphasis on project management. Through an exhaustive analysis of recent literature spanning several crucial years, it has become clear that the pandemic has not only intensified pre-existing challenges but also prompted the industry to innovate and adapt in ways previously unconsidered. The swift implementation of diverse intervention measures, from stringent health protocols to strategic workforce management, has underscored the industry's capacity to respond to crisis situations dynamically. The application of Adaptive Chaos Management Theory within this context has provided valuable insights into the non-linear dynamics and unpredictable nature of construction project management during global disruptions. The theory demonstrates how small changes in initial conditions can lead to significant impacts on project outcomes, emphasizing the need for adaptive strategies that can accommodate sudden shifts in operational contexts.

This review has highlighted both the successes and shortcomings of the interventions adopted, pointing to the necessity for continuous evaluation and adaptation of strategies based on empirical evidence and theoretical frameworks. The findings advocate for a more resilient and flexible construction industry that can not only withstand future pandemics but also thrive amidst the chaos they bring. As the construction industry continues to navigate the aftermath of the COVID-19 pandemic, the insights garnered from this review will be invaluable in shaping more effective and sustainable management practices. The synthesis of empirical data and theoretical perspectives presented here not only advances academic understanding but also serves as a foundational resource for practitioners in the field, ultimately enhancing the robustness and efficiency of construction project management in facing future global challenges.

3. Methodology

3.1 A Positivist Philosophy by Quantitative Design

Adhering to the Positivist Research Philosophy, this study prioritized unbiased fact-gathering, uninfluenced by subjective interpretation. It employed a deductive approach for theoretical generalization of the data collected. Utilizing an online questionnaire as a survey strategy facilitated the collection of extensive, consistent data. This method ensured the study's objectivity and allowed for quantitative analysis. A linear regression model supported the removal of speculative elements concerning COVID-19. The investigation provided a cross-sectional view of COVID-19's impact on South Africa from March 2020 to June 2022 [140]. Purposive sampling selected a representative cohort of participants from the South African construction industry to enhance the study's generalizability, mirroring the broader sub-population. The sample was used as a reflection of the sub-population from which participants were drawn [141]. This research specifically targeted contractors, leveraging their expertise to achieve the study's objectives.

3.2 Data Collection from South African Construction Entities

This study targeted ten South African entities through social media, texts, direct interactions, and emails, aiming to secure a minimum of ten permission letters for participation

[142,143]. Selection was randomized to mitigate bias, prioritizing entities appearing at the forefront of search engine results and those within accessible proximity. The survey's background questions, designed for validity, interconnected to guide subsequent inquiries, such as correlating a contractor's project value with its workforce size [144]. Companies were contacted to share contact details, with those found on Google receiving emails directly from their listed information. Upon receiving consent and ethical clearance, participants were sent an online questionnaire link, which included an information sheet emphasizing that questionnaire submission constituted consent to participate [140]. The survey, conducted from March 2020—marking the onset of the COVID-19 pandemic—was designed to be completed within 10 to 15 minutes , ultimately garnering 62 responses [145].

3.3 SPSS Analysis of Survey Data by Company Size, Project Size, and Timelines

Survey data were analyzed using the Statistical Package for Social Sciences (SPSS) via a linear regression model [146]. The analysis segmented data into three primary categories: participants from large versus small/medium-sized construction firms, as classified by the Construction Industry Development Board (CIDB) grade ; project size; and the initiation date of the projects [147,148]. This categorization aimed to discern the influence of project commencement periods on success rates, accounting for project scale. Descriptive statistics and regression analysis facilitated the examination of these variables, with tables, graphs, and relationship maps illustrating the findings. Participant confidentiality was paramount, with anonymity preserved throughout the study [149,150]. The questionnaire was designed to detect inconsistencies, featuring multiple-choice and Likert scale questions for comprehensive data collection and enhanced accuracy of results. Clarity and comprehensibility were key in question design, ensuring uniform interpretation across respondents [142].

3.4 Statistical Analysis of Workforce Reduction Impact on Project Timelines

The study's data was analysed utilizing the formula $Y = f_0 + f_1(wfr)_1 + \varepsilon$ (1), where the dependent variable (Y) signified the project turnaround time, and workforce reduction (wfr) served as the independent variable (X). This analytical model yielded a precise coefficient, accompanied by a standard error, facilitating the evaluation of the study's significance by quantifying the impact of workforce reduction on project completion time.

4. Results

4.1 Introduction

This section reinforces prior discussions by presenting the outcomes of hypothesis testing introduced earlier. It juxtaposes the survey results against the reviewed literature, employing a linear regression model alongside descriptive statistics and relationship maps within SPSS for analysis [151]. The participation of 62 individuals exceeded the threshold for robust findings, aligning with the recommendation of a 15:1 participant-to-research-study ratio as indicative of dependable outcomes. The absence of missing responses underscored the data's completeness. Focused on CIDB-registered contractors, the survey disclosed predominant participation from contractors within Grade 7, 8, 9, and 2, recording participation rates of 21%, 14.5%, and 12.9% for Grades 9 and 2, respectively. Additionally, 22.6% of respondents categorized themselves as "other," not aligning with provided CIDB grades, among which 3.2% identified as Grade 1 contractors, with the remainder not associating with any specific CIDB grade.

Table A1. Contractors' Project Background Information.

QUESTION	CLASS	FREQ.	%	VALID %	CUMULATIVE %
What was the contract amount you were working on during COVID-19?	<R1 000 000	9	14.5	14.5	14.5
	R1 000 000 – R3 900 000	7	11.3	11.3	25.8
	R4 000 000 – R10 900 000	7	11.3	11.3	37.1
	R11 000 000 – R35 900 000	16	25.8	25.8	62.9
	R36 000 000 – R100 000 000	11	17.7	17.7	80.6
	>R100 000 000	12	19.4	19.4	100.0
	Total	62	100.0	100.0	
How far along is your project?	1%–49%	8	12.9	12.9	12.9
	50%	5	8.1	8.1	21.0
	51%–99%	25	40.3	40.3	61.3
	100%	24	38.7	38.7	100.0
	Total	62	100.0	100.0	
How many workers did you have on your project?	Less than 10	10	16.1	16.1	16.1
	From 10 to 30	23	37.1	37.1	53.2
	From 31 to 50	9	14.5	14.5	67.7
	From 51 to 80	8	12.9	12.9	80.6
	From 81 to 100	4	6.5	6.5	87.1
	More than 100	8	12.9	12.9	100.0
	Total	62	100.0	100.0	

Table A1 classifies data into three main categories relevant to the study: contract amounts during COVID-19, project progress, and workforce size. Each category is essential for understanding the impact of the pandemic on the South African construction industry.

4.2 Contract Amount

The data ranges from less than R1 million to over R100 million. Most projects (25.8%) fell in the R11 million to R35.9 million range, indicating that middle-range projects were most common during COVID-19. The distribution shows that significant portions of the projects (19.4%) involved contracts over R100 million, suggesting that high-value projects continued despite the pandemic, possibly due to their critical nature or prior financial commitments.

4.3 Project Progress

Most of the projects were either nearly completed or fully completed during the pandemic, with 38.7% fully completed and 40.3% between 51%-99% completion. Only a small fraction of the projects was less than half completed (12.9%), which might indicate effective management or adaptation strategies that prevented severe delays.

4.4 Workforce Size

Workforce sizes varied significantly, but the largest segment (37.1%) consisted of projects employing between 10 to 30 workers, aligning with middle-range project values. Projects with more than 100 workers accounted for 12.9% of the total, reflecting the scale of operations required for larger projects.

4.5 Descriptive Analysis

The data from this table is crucial for understanding the dynamics of project management during the pandemic. It suggests a concentration of ongoing construction activities in mid to high-value projects, with a significant portion nearing completion despite COVID-19

disruptions. The variance in workforce size indicates diverse strategies and adaptations to pandemic restrictions, possibly reflecting different degrees of automation, outsourcing, or remote management capabilities across projects. Understanding these dynamics helps in assessing the resilience of the construction sector and the effectiveness of strategies employed to mitigate the impact of COVID-19, particularly in terms of managing skilled labor and maintaining project schedules. This analysis provides a quantitative foundation to evaluate the broader implications of COVID-19 on project timelines and financial stability within the construction industry, aligning with the study's objectives to explore the effects of skilled labor reduction and the application of the Adaptive Chaos Management Theory in Construction. This trend suggests that participants engaged in larger projects during the COVID-19 pandemic likely adopted more stringent and careful approaches compared to those involved in smaller projects [152].

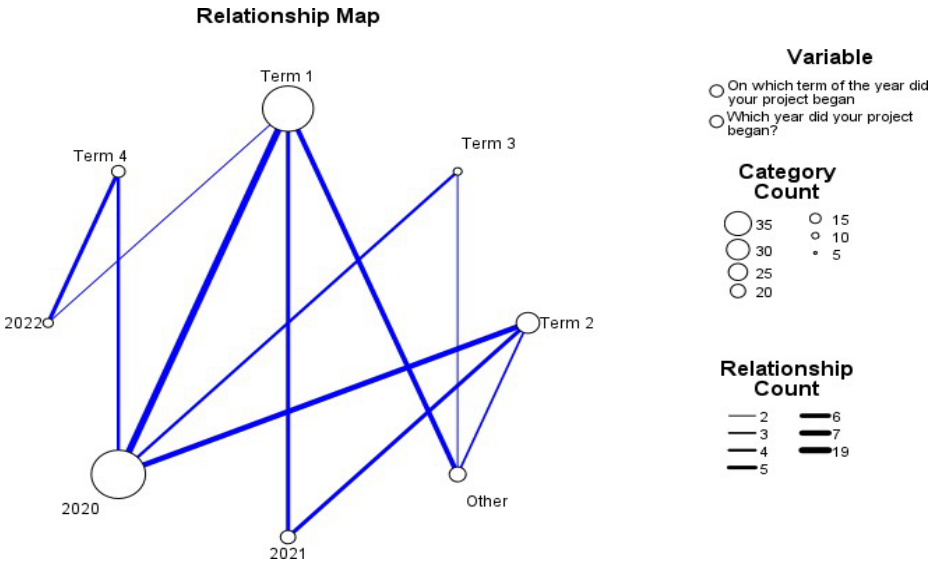

Figure 2: The Relationship Between the Year and Term Construction Projects Began.

The graph presented in Figure 2 is a relationship map focusing on the timing of project commencements within the context of the COVID-19 pandemic's impact on the construction industry. The graph uses nodes to represent different terms of the year (Term 1 through Term 4 and "Other"), as well as two specific years (2020 and 2021). These terms correspond to the quarters of the year when construction projects began. Each node size correlates with the number of projects that began in that term or year, with larger nodes representing a higher number of project initiations. The scale provided (5, 10, 15, 20, 25, 30, 35) suggests a quantitative measure of the projects per term/year. The term/year with the largest node (most projects started) would be significant in assessing the impact of COVID-19 on project initiation timelines. Lines connect various terms and years, indicating relationships or comparisons between when projects were initiated. The thickness of the line correlates to the frequency of relationships (2 to 19 times), indicating transitions or shifts in project scheduling from one term or year to another.

4.6 Project Start Timeline Relationship Map

This map is essential for visualizing how the pandemic caused shifts in project planning and initiation across different times. It supports an examination of patterns in how projects were either clustered or spread out over specific terms, reflecting the industry's response to

unfolding pandemic-related disruptions. The map identifies periods of heightened activity or notable delays, which are correlated with specific events or phases of the pandemic, such as lockdowns or changes in public health policy. Understanding these patterns is crucial for evaluating the impact of skilled labor reductions and other pandemic-induced challenges on project turnaround times. Analyzing the timing of project starts provides insights into how workforce disruptions influenced project schedules and deadlines, potentially leading to the formulation of strategies to mitigate similar impacts in the future. This relationship map serves as a foundational tool for dissecting the temporal dynamics of the construction industry's project management strategies during the pandemic, providing empirical data to support hypotheses related to project delays and management adaptations.

4.7 Arguments from the Status Quo

new construction projects in the United Kingdom (UK) were significantly affected by COVID-19 [63]. Figure 2 illustrates the temporal commencement of participants' projects, revealing that the majority were initiated in the first and second terms of 2020. This timeframe coincides with the initial declaration and peak of the COVID-19 pandemic, indicating a direct impact on these construction endeavors. There is a significant negative impact of skilled labor reduction on construction project turnaround times during the COVID-19 pandemic in South Africa. This hypothesis argued that reductions in skilled labor due to COVID-19 are statistically associated with increased project completion times, thereby adversely affecting project schedules.

4.8 Minimal Workforce Loss Due to COVID-19 Skews Toward Skilled Workers, Affecting Project Timelines

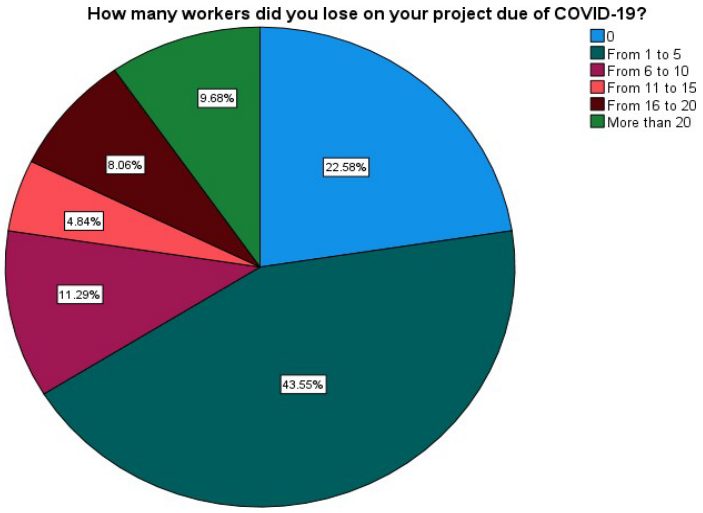

Figure 3: Workforce Loss on South African Construction Projects During COVID-19.

The pie chart in Figure 3 illustrates the distribution of workforce losses on construction projects due to COVID-19, categorized by the number of workers lost. Analyzing this chart provides valuable insights into how the pandemic affected labor availability on construction sites, a crucial aspect of the study focusing on the impacts of skilled labor reduction on project timelines.

4.8.1 No Loss (22.58%)

This segment, representing nearly a quarter of the participants, indicates projects where no workers were lost. This suggests that a significant portion of projects managed to retain their workforce, potentially maintaining project schedules more effectively.

4.8.2 Loss of 1 to 5 Workers (43.55%)

The largest segment, almost half of the responses, experienced minimal workforce reductions. While these projects lost a few workers, the impact might vary based on the total size of the workforce and the roles of those lost.

4.8.3 Loss of 6 to 10 Workers (11.29%) and 11 to 15 Workers (8.06%)

These categories show moderate workforce losses. Projects with such reductions experience more substantial delays, especially if the lost workers were in skilled or critical positions.

4.8.4 Loss of 16 to 20 Workers (4.84%) and more than 20 Workers (9.68%)

These smaller segments represent projects with significant labor losses. Projects in these categories are likely to face considerable challenges in meeting project deadlines, requiring adjustments in project management strategies to mitigate delays.

This distribution is critical for understanding the scale of workforce disruptions across different project sizes and types, informing the study's examination of management strategies and the application of the Adaptive Chaos Management Theory in mitigating the impacts of such disruptions on project timelines.

Figure 4: Skilled Worker Reduction and Delay Impact in Construction Projects.

This bar chart presented in Figure 4 represents the distribution of opinions among survey participants regarding the statement: "Workforce reduction led to a loss in skilled workers, resulting in delayed task completion." The responses are categorized across a Likert scale ranging from "Strongly Disagree" to "Strongly Agree" [153,154].

Strongly Disagree: A small minority (6.45%) of respondents strongly disagree that reductions in the workforce, specifically skilled workers, have led to delays in task completion.

Disagree: A slightly larger segment (16.13%) disagrees, suggesting that they do not perceive a direct impact of workforce reduction on delays or have experienced different circumstances that mitigated such impacts.

Neutral: A quarter of the participants (25.81%) remain neutral. This indicates uncertainty or a lack of direct experience with delays caused by the loss of skilled workers.

Agree and Strongly Agree: Each of these categories also captures 25.81% of responses, indicating that a significant portion of the sample—more than half when combined—acknowledges a direct connection between the reduction in skilled workforce and the resultant delays in project milestones.

This distribution depicts a relatively even split in perceptions, with a significant number acknowledging the impact of skilled worker reduction on project timelines, while others are less convinced of this causality. The results highlight the need for further investigation into the factors that might influence differing experiences and perceptions, such as project type, management strategies, and the specific roles of skilled workers within project teams [155].

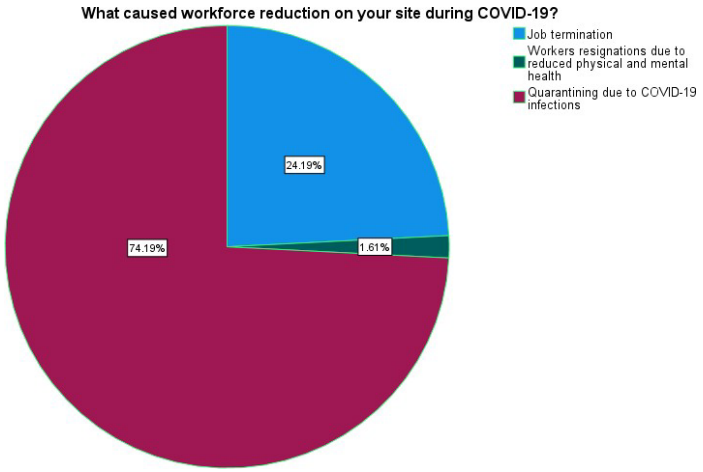

Figure 5: Causes of Workforce Reduction During COVID-19 in Construction.

The pie chart visualizes the primary causes of workforce reduction on construction sites during the COVID-19 pandemic as perceived by the study participants. The largest segment, comprising 74.19% of the responses, attributes workforce reduction predominantly to quarantining due to COVID-19 infections. This highlights the significant impact that health safety measures and infection control had on staffing levels. The second major cause, accounting for 24.19% of the responses, is job termination, indicating that employment cuts were also a notable factor in workforce changes. A much smaller segment, 1.61%, represents workers' resignations due to reduced physical and mental health, suggesting that personal health concerns played a minor role compared to other factors. This distribution underscores the overwhelming influence of pandemic-related health protocols on workforce availability, aligning with the study's focus on understanding the broader impacts of COVID-19 on project management and completion within the construction industry [156,157].

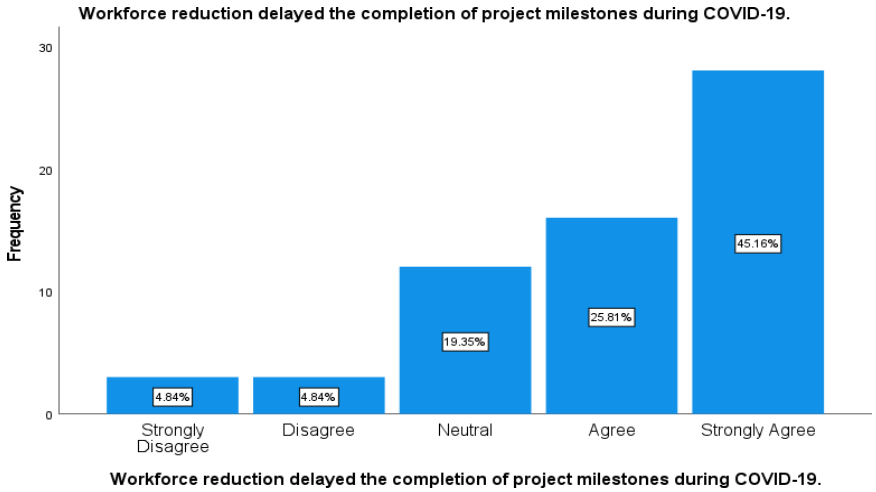

Figure 6: Workforce Reduction's Effect on Project Milestones During COVID-19.

The bar chart in Figure 6 displays survey responses on the perceived impact of workforce reduction on the completion of project milestones during the COVID-19 pandemic. The responses are categorized across a Likert scale ranging from "Strongly Disagree" to "Strongly Agree" [153,154].

Strongly Disagree (8.49%): A small fraction of the respondents, about 8.49%, strongly disagree that workforce reduction delayed project milestones. This depicts that for these respondents, reductions in workforce did not translate into noticeable delays, possibly due to effective management strategies or the nature of their specific projects.

Disagree (8.49%): An equal percentage of respondents also disagree, indicating a similar sentiment that workforce reduction did not significantly impact their project timelines.

Neutral (19.35%): Nearly a fifth of the participants are neutral, suggesting they might not have observed a direct correlation between workforce reduction and project delays, or they may have seen varying impacts that do not lead them to lean strongly towards agreement or disagreement.

Agree (25.81%): Over a quarter of respondents agree that there was a delay in project completion due to reduced workforce, supporting the idea that fewer hands-on deck can lead to slower progress.

Strongly Agree (45.16%): The majority, nearly half of the respondents, strongly agree that the reduction in workforce led to delays in completing project milestones. This strong agreement depicts a significant perception or experience of impact, reduced workforce capacity critically affected project timelines.

This data is crucial for understanding the real-world impacts of workforce disruptions in the construction industry during the pandemic. It illustrates a significant acknowledgment of the challenges posed by reduced labor availability, emphasizing the need for robust workforce management and contingency planning in construction project management to mitigate such risks as posited through the lens of Adaptive Chaos Management Theory.

4.9 Finding Nuance and Connections in COVID19 Skilled Construction Workforce Data

As illustrated by Figures 2 through 6, COVID-19's impact on workforce reduction at construction sites was minimal. The predominant categories of job loss were 0 workers, 1–5 workers, and 6–10 workers due to COVID-19. A significant 62% of participants concurred that most job losses involved skilled workers, with 25.81% remaining neutral. Quarantining emerged as the principal reason for workforce reduction, closely followed by job termination. Despite the overall minor reduction in workforce numbers, the skill level of those lost was notably high, with 70.97% affirming that such reductions consequently delayed project activities and milestones. This was further supported by 77.42% of respondents in Figure 4, who noted their projects suffered from the loss of skilled labor. Conversely, 22.58% disputed that project delays were directly linked to skilled worker shortages, aligning with Figure 3 findings where an equal percentage reported no job loss due to COVID-19. Notably, most respondents managed projects with 10 to 30 workers, suggesting a maximum potential job loss average of 16.67%, explaining the neutral responses. The attribution of workforce reduction primarily to quarantining is logical, given the indiscriminate nature of COVID-19 infections relative to workers' skill levels. Figure 6, aligning with Figure 4, revealed that over 50% of participants recognized workforce reduction as a significant factor delaying site activities, echoing findings from the literature, and underscoring the global challenges faced by contractors. In the United States, the pervasive impact of COVID-19, particularly through worker infections, significantly hindered project timelines [63]. This observation was corroborated by Shibani et al., who highlighted that implementing shift work as a precaution only resulted in further delays due to reduced staffing levels [119].

4.10 Mixed Views on COVID-19 Interventions Improving Construction Schedules

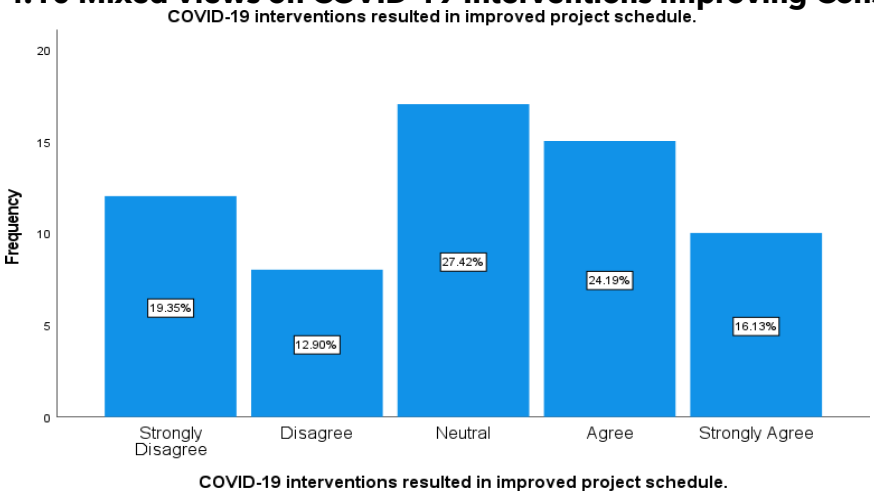

Figure 7: Impact of COVID-19 Interventions on Construction Project Schedules.

A notable neutrality was observed among participants regarding the efficacy of COVID-19 interventions on enhancing project schedules. In related research from the USA, some respondents reported minimal disruption to construction activities due to COVID-19, albeit acknowledging the necessity of implementing new safety protocols [63]. Among the respondents, those in agreement were outnumbered by neutrals, followed by strong disagreement, with strong agreement and disagreement ranking fourth and fifth, respectively. In confirming the study's second hypothesis, (H2), current project management strategies in the South African construction industry are insufficient for effectively addressing the disruptions caused by workforce reductions during the COVID-

19 pandemic. The testing of this hypothesis, existing project management practices, when assessed in light of pandemic-induced challenges, will demonstrate shortcomings in effectiveness, highlighting the necessity for enhanced strategies or approaches.

4.11 Chronology of Construction Project Recovery Post-COVID Delays

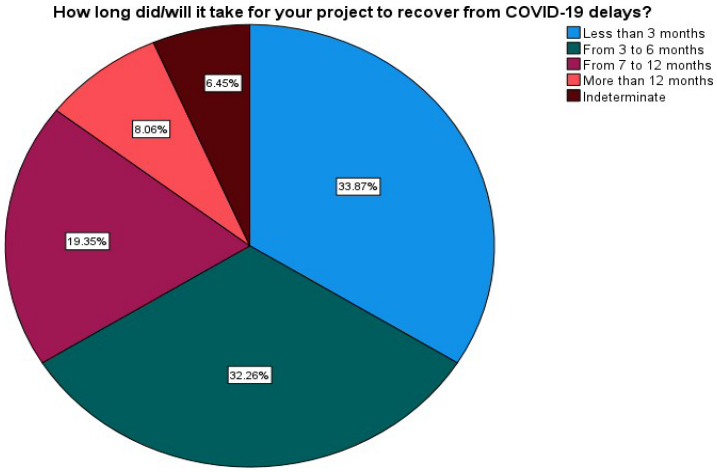

Figure 8: Project Recovery Time from COVID-19 Delays in Construction Industry.

Participants reported a sequential pattern regarding their projects' recovery times from COVID-19-induced delays. The majority stated their projects would recover in less than 3 months. However, a deeper dive into the recovery timelines relative to project size and CIDB grades of contractors would further enrich the construction industry's understanding. Following the majority, 32.26% of respondents anticipated a recovery period of 3 to 6 months, with 19.35% projecting 7 to 12 months for project normalization. A smaller fraction, 8.06%, foresaw a recovery extending beyond 12 months, while 6.45% were uncertain about the duration required for their projects to overcome the delays caused by COVID-19. The application of principles from the Adaptive Chaos Management Theory in Construction (ACMTC) significantly enhances the management of construction projects during workforce disruptions caused by pandemics. This hypothesis maintains that the incorporation of ACMTC into project management during pandemic conditions results in improved management outcomes, thereby proving the theory's practical value and effectiveness in boosting project resilience and adaptability.

5. Discussion

5.1 CIDB Grade Representation in South African Construction Study Participation

Data collection targeted contractors within the South African construction industry, with participation limited to those who provided consent through letters. The survey captured representatives across all CIDB grades, though significant representation was seen in only five categories. The "other" category received limited responses, with two indicating employment at Grade 1 contracting firms, and the remainder comprised Implementing Agents, Consulting Engineers, or those unaffiliated with any specific CIDB grade. It is hypothesized that the research link was disseminated among entire project teams by participating companies, thus including a variety of professionals such as Implementing Agents and Consulting Engineers.

5.2 CIDB Grading Influence on Contractor Project Scope and COVID-19 Impact

The Construction Industry Development Board (CIDB) stipulates that a contractor's maximum project value aligns with their CIDB grading; however, government projects may permit small/medium-scale contractors to engage in larger projects as subcontractors due to a mandatory 30% subcontracting rule [147,158,159]. This study's outcomes indicated the highest participant representation in projects valued at R11,000,000 and above, signifying substantial involvement from large construction firms. Nevertheless, small/medium-scale contractors were also well represented, with 37.1% of participants from firms tendering at R10,000,000 and below, indicating their significant presence. Among respondents, 40.3% were involved in projects 51%-99% complete, with 38.7% on projects already completed at the time of the survey, and 29% working on projects 50% or less complete. The aggregation of 79% participants from projects either completed or more than halfway through underscores the reliability of the findings, reflecting comprehensive experiences of COVID-19's impact. Conversely, 21% of responses came from projects 1%-49% complete, likely initiated in late 2021 or early 2022, offering insights into the pandemic's evolving effects. A notable portion of participants worked on projects with 10 to 30 workers, suggesting significant representation from Grade 6 contractors and above, based on the proportional relationship between project value and workforce size. This delineation suggests that projects with more than 30 workers fall into the larger project category, while projects with 10 or fewer workers were considered small-scale. The commencement date of projects provided valuable data, enhancing the comparability of findings, and affirming the study's methodology.

5.3 Minimal Workforce Impact From COVID-19 on South African Construction Sites

The findings indicated that most participants experienced minimal loss of workforce on their sites, while a notable second group reported no impact from COVID-19 on their workforce composition. Such variance within a single study's responses is both intriguing and illustrative of the diverse impacts of the pandemic across the construction sector. Contrary to prevailing literature, which suggests significant workforce reductions as migrant workers returned home, our findings presented a different narrative. Stiles et al. noted that the UK saw a decrease in skilled labor availability on construction sites due to illness or social distancing measures aimed at controlling COVID-19 [152]. These outcomes align with the project sizes of our respondents, primarily indicating participation from larger projects. It was anticipated that larger contractors, benefiting from substantial turnovers, would reallocate resources within their operations to mitigate the impact of a diminished workforce. Responses regarding other impacts were evenly spread, showing little variation across different categories.

5.4 Quarantining as Primary Cause of Workforce Loss in Construction During COVID-19

The results demonstrated that a significant proportion of participants experienced workforce losses on their construction sites due to COVID-19. These findings detailed the primary reasons for such reductions, with nearly three-quarters attributing worker shortages to quarantining necessitated by COVID-19 infections. Ogunnusi et al. echoed this, observing that in the UK, governmental mandates on social distancing significantly dwindled the workforce, thereby extending project timelines [56]. A similar scenario was reported in Singapore, where the isolation of foreign workers, a critical labor force in the construction sector, due to heightened infections in dormitories, led to project delays [160].

Job termination emerged as the secondary cause for workforce reduction, a predictable outcome [161]. Additionally, a small fraction (1.61%) of respondents indicated job departures due to deteriorating physical and mental health amidst the pandemic. The predominance of responses suggesting that workforce reduction, particularly of skilled workers, led to project milestone delays highlighted the critical nature of such research, revealing unexpected data outcomes. Furthermore, the existence of participants from projects unaffected by labor shortages suggests a nuanced understanding of the factors behind project delays, underscoring the importance of comprehensive analysis in attributing causes to observed effects.

5.5 Mixed Reactions to COVID-19 Interventions' Effect on Project Schedules

A total of 40.32% of participants concurred or strongly concurred that COVID-19 interventions positively impacted project schedules, yet over half expressed disagreement, strong disagreement, or neutrality, underscoring the relevance of this investigation. This division prompts inquiries into the anticipated timeline for project recovery, a question to which Alsharef et al. found that many US study participants could not provide definite timelines due to the multifaceted influences of COVID-19 on project execution [63]. Olanrewaju et al. revealed that health and safety protocols could potentially reduce site productivity by half, suggesting similar project delays [162]. Consequently, it is advised that future unforeseen events with the potential for widespread disruption, akin to COVID-19, should prompt the Built Environment and contractors to proceed with caution, leveraging lessons from past pandemics to assess the efficacy and impact of proposed measures. The affirmation of the study's hypothesis, derived from its research question and objectives, signifies the achievement of the research aim, validating the necessity for cautious and informed intervention strategies in the face of pandemics.

5.6 Confirming Adaptive Chaos Management Theory in Construction Project Management

This study's results highlight the necessity for the construction industry to embrace adaptability and resilience, enabling it to navigate through and evolve amid the chaos introduced by global health emergencies [77,89,90,92,106,163–169]. The research advocates that proactive adaptation, and the implementation of flexible management strategies can mitigate the adverse effects of such disruptions [104,105,111,112,127,139,170]. The emergence of new, more effective construction management practices in response to the pandemic illustrates the potential for industry evolution, driven by crisis-induced innovation [86,88,98,127,171]. Conclusively, the Adaptive Chaos Management Theory in Construction, rooted in the empirical findings of this study, provides a robust framework for understanding and managing the complex dynamics of construction projects during pandemics. This theory not only enriches academic discourse but also offers practical insights for industry practitioners, aiming to enhance project management strategies in the face of unpredictable global challenges. This alignment of theory with empirical evidence encapsulates the study's contribution to both the theoretical and practical dimensions of construction project management, paving the way for future research to build upon these foundational insights.

The successful application of the Adaptive Chaos Management Theory in Construction (ACMTC) within the context of the COVID-19 pandemic has significantly advanced the understanding of the construction industry's capacity to cope with and thrive amid unprecedented global disruptions. This theory, grounded in Chaos Theory, has

demonstrated its robustness through the validation of its four key tenets in the real-world scenario of the pandemic's impact on the construction sector. The pandemic's outbreak acted as a practical test for these tenets, revealing how minor disruptions could escalate into significant challenges affecting project timelines and workforce dynamics. The theory's prediction of non-linear outcomes has been borne out, as construction projects encountered unexpected delays and complications, underscoring the critical need for project management frameworks that anticipate and plan for such unpredictability. These tenets have proven essential in fostering a strategic approach to managing unforeseeable shifts in the construction landscape.

ACMTC has not only provided a theoretical framework for understanding the impacts of the COVID-19 pandemic on the construction industry but has also offered practical insights that can guide future responses to similar crises. The industry's journey through the pandemic has proven the indispensability of embracing chaos as an opportunity for growth and innovation, thereby transforming challenges into catalysts for enduring advancements in construction project management.

6. Conclusion

Lockdown restrictions within the construction sector prompted the adoption of measures to counteract resulting delays, driving this study to examine the impact of workforce reduction on project completion times in the South African construction industry [172]. Despite COVID-19's relatively minor effect on overall workforce numbers, the loss of even a small number of skilled workers significantly hindered project progress, primarily due to quarantine and isolation protocols. Consequently, many projects failed to meet their milestones within the anticipated timelines, underscoring the profound impact of skilled labor shortages on construction site operations. Nonetheless, this study sheds light on the nuanced effects of workforce reduction, offering insights that may pique the interest of researchers in South Africa and beyond, seeking to explore the broader ramifications of such challenges on a global scale.

7. Recommendations

7.1 Industry Recommendations

7.1.1 Adoption of Flexible Workforce Strategies

Construction companies should adopt flexible workforce strategies, including multi-skilling and cross-training of workers, to mitigate the impact of skilled labor shortages during pandemics. By diversifying workers' skills, companies can ensure that project milestones are met even when specific skilled workers are unavailable due to health-related absences.

7.1.2 Implementation of Robust Health and Safety Protocols

The industry should develop and implement robust health and safety protocols that can be swiftly activated in response to pandemics. These protocols should include regular health screenings, provision of personal protective equipment (PPE), and clear guidelines for quarantine and isolation to minimize workforce disruptions.

7.1.3 Investment in Technology and Automation

To reduce dependency on manual labor, the construction industry should invest in technology and automation. Utilizing advanced construction technologies such as Building

Information Modeling (BIM), drones, and robotic automation can enhance project efficiency and reduce the impact of workforce shortages.

7.2 Policy Recommendations

7.2.1 Development of Pandemic Response Guidelines for Construction

Governments should develop comprehensive pandemic response guidelines specifically tailored for the construction industry. These guidelines should address workforce management, health and safety protocols, and project timeline adjustments to ensure continuity during health crises.

7.2.2 Incentives for Technological Advancements

Policymakers should provide incentives for construction firms to adopt technological innovations. Grants, tax breaks, and subsidies for investments in automation and digital tools can help the industry become more resilient to future disruptions.

7.2.3 Support for Training and Development Programs

Governments should support training and development programs that focus on upskilling construction workers. By promoting continuous learning and skill diversification, the workforce can better adapt to changing project demands and mitigate the impact of labor shortages.

7.3 Academic Recommendations

7.3.1 Further Research on Workforce Management During Pandemics

Academia should conduct further research on workforce management strategies during pandemics. Studies should explore the effectiveness of different intervention measures, including shift work, remote work, and multi-skilling, to provide empirical data that can guide industry practices.

7.3.2 Exploration of Technological Impacts on Project Management

Researchers should investigate the impact of technological advancements on construction project management during pandemics. Studies should examine how technologies such as BIM, drones, and automation influence project timelines, labor requirements, and overall efficiency.

7.3.3 Development of Theoretical Frameworks for Crisis Management

Academia should develop and refine theoretical frameworks for crisis management in the construction industry. The Adaptive Chaos Management Theory in Construction (ACMTC) provides a foundation, but further work is needed to expand its application and validate its principles across different types of crises.

7.4 Framework for Resilience in Construction

The following framework integrates the recommendations for industry, policy, and academia to enhance resilience in the construction industry during pandemics and other crises:

7.4.1 Preparedness and Planning

- Develop and implement comprehensive health and safety protocols.
- Create flexible workforce strategies, including multi-skilling and cross-training.

- Establish clear communication channels for timely dissemination of guidelines and updates.

7.4.2 Technological Integration

- Invest in advanced construction technologies such as BIM, drones, and automation.
- Encourage continuous technological innovation and adoption within the industry.
- Provide training programs to enhance digital literacy and technological competencies among workers.

7.4.3 Policy Support and Incentives

- Develop government guidelines and policies specifically for managing construction projects during pandemics.
- Offer financial incentives for technological investments and workforce training programs.
- Collaborate with industry stakeholders to ensure policies are practical and effective.

7.4.4 Research and Development

- Conduct empirical studies on the effectiveness of different workforce management strategies during pandemics.
- Explore the impact of technological advancements on project management and efficiency.
- Develop and validate theoretical frameworks for crisis management, such as ACMTC, to guide industry practices.

7.4.5 Continuous Improvement

- Monitor and evaluate the effectiveness of implemented strategies and protocols.
- Adjust and refine measures based on feedback and new research findings.
- Promote a culture of continuous learning and adaptation within the construction industry.

8. Funding

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9. Acknowledgments

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10. Conflict of Interest Statement

The authors declare no conflicts of interest.

11. Data Availability Statement

The dataset analysed during the current study is not publicly available due to concerns regarding personal privacy and confidentiality. The research dataset involves sensitive information that could potentially identify individual participants, thus necessitating stringent measures to protect privacy in accordance with ethical guidelines and legal requirements. Access to the data is restricted to the research team and is unavailable to the public. The data used is depicted in Table A1. Contractors' Project Background Information.

12. References

[1] B. Wang, Y. Liu, J. Qian, S.K. Parker, Achieving Effective Remote Working During the COVID-19 Pandemic: A Work Design Perspective, Appl. Psychol. 70 (2021) 16–59. https://doi.org/10.1111/apps.12290.

[2] S.R. Baker, N. Bloom, S.J. Davis, K. Kost, M. Sammon, T. Viratyosin, The Unprecedented Stock Market Reaction to COVID-19, Rev. Asset Pricing Stud. 10 (2020) 742–758. https://doi.org/10.1093/rapstu/raaa008.

[3] H. Tegally, E. Wilkinson, M. Giovanetti, A. Iranzadeh, V. Fonseca, J. Giandhari, D. Doolabh, S. Pillay, E.J. San, N. Msomi, Detection of a SARS-CoV-2 Variant of Concern in South Africa, Nature 592 (2021) 438–443. https://doi.org/10.1038/s41586-021-03402-9.

[4] J.J.V. Bavel, K. Baicker, P.S. Boggio, V. Capraro, A. Cichocka, M. Cikara, M.J. Crockett, A.J. Crum, K.M. Douglas, J.N. Druckman, J. Drury, O. Dube, N. Ellemers, E.J. Finkel, J.H. Fowler, M. Gelfand, S. Han, S.A. Haslam, J. Jetten, S. Kitayama, D. Mobbs, L.E. Napper, D.J. Packer, G. Pennycook, E. Peters, R.E. Petty, D.G. Rand, S.D. Reicher, S. Schnall, A. Shariff, L.J. Skitka, S.S. Smith, C.R. Sunstein, N. Tabri, J.A. Tucker, S.V.D. Linden, P.V. Lange, K.A. Weeden, M.J.A. Wohl, J. Zaki, S.R. Zion, R. Willer, Using Social and Behavioural Science to Support COVID-19 Pandemic Response, Nat. Hum. Behav. 4 (2020) 460–471. https://doi.org/10.1038/s41562-020-0884-z.

[5] D. Huremović, Brief History of Pandemics (Pandemics Throughout History), Psychiatry Pandemics Ment. Health Response Infect. Outbreak (2019) 7–35. https://doi.org/10.1007/978-3-030-15346-5_2.

[6] M. Park, A.R. Cook, J.T. Lim, Y. Sun, B.L. Dickens, A Systematic Review of COVID-19 Epidemiology Based on Current Evidence, J. Clin. Med. 9 (2020) 967. https://doi.org/10.3390/jcm9040967.

[7] M. Coccia, Factors Determining the Diffusion of COVID-19 and Suggested Strategy to Prevent Future Accelerated Viral Infectivity Similar to COVID, Sci. Total Environ. 729 (2020) 138474. https://doi.org/10.1016/j.scitotenv.2020.138474.

[8] R.Y. Elbay, A. Kurtulmuş, S. Arpacıoğlu, E. Karadere, Depression, Anxiety, Stress Levels of Physicians and Associated Factors in COVID-19 Pandemics, Psychiatry Res. 290 (2020) 113130. https://doi.org/10.1016/j.psychres.2020.113130.

[9] S. Ullah, G. Zaefarian, R. Ahmed, D. Kimani, How to Apply the Event Study Methodology in STATA: An Overview and a Step-by-Step Guide for Authors, Ind. Mark. Manag. 99 (2021) A1–A12.

[10] I. Ali, O.M. Alharbi, COVID-19: Disease, Management, Treatment, and Social Impact, Sci. Total Environ. 728 (2020) 138861. https://doi.org/10.1016/j.scitotenv.2020.138861.

[11] A. Sharma, D. Ghosh, N. Divekar, M. Gore, S. Gochhait, S. Shireshi, Comparing the socio-economic implications of the 1918 Spanish flu and the COVID-19 pandemic in India: A systematic review of literature, Int. Soc. Sci. J. 71 (2021) 23–36. https://doi.org/10.1111/issj.12266.
[12] S. Brammer, L. Branicki, M.K. Linnenluecke, COVID-19, Societalization, and the Future of Business in Society, Acad. Manag. Perspect. 34 (2020) 493–507. https://doi.org/10.5465/amp.2019.0053.
[13] M. Nyashanu, P. Simbanegavi, L. Gibson, Exploring the Impact of COVID-19 Pandemic Lockdown on Informal Settlements in Tshwane Gauteng Province, South Africa, Glob. Public Health 15 (2020) 1443–1453. https://doi.org/10.1080/17441692.2020.1805787.
[14] R.Y. Elbay, A. Kurtulmuş, S. Arpacıoğlu, E. Karadere, Depression, Anxiety, Stress Levels of Physicians and Associated Factors in Covid-19 Pandemics, Psychiatry Res. 290 (2020) 113130. https://doi.org/10.1016/j.psychres.2020.113130.
[15] K. Adhikari, L. Poudyal, Future of Construction Industry: Covid-19 and Its Implications on Construction Projects and Risk Management – A Review, (2021). https://doi.org/10.20944/preprints202104.0383.v1.
[16] H.T. Pham, H.T. Quang, P. Sampaio, M. Carvalho, D.L.A. Tran, V.X. Vo, B.A.T. Duong, The Impact of Global Risks on Supply Chain Performance. an Empirical Study on Construction Sector in the COVID-19 Pandemic, Int. J. Qual. Reliab. Manag. 40 (2022) 1009–1035. https://doi.org/10.1108/ijqrm-03-2022-0084.
[17] M. Ogunnusi, M. Hamma-Adama, H. Salman, T. Kouider, COVID-19 Pandemic: The Effects and Prospects in the Construction Industry, Int. J. Real Estate Stud. 14 (2020).
[18] M. Ogunnusi, T. Omotayo, M. Hamma-Adama, B.O. Awuzie, T. Egbelakin, Lessons Learned from the Impact of COVID-19 on the Global Construction Industry, J. Eng. Des. Technol. 20 (2021) 299–320. https://doi.org/10.1108/jedt-05-2021-0286.
[19] C.O. Aigbavboa, D.O. Aghimien, W.D. Thwala, M.N. Ngozwana, Unprepared Industry Meet Pandemic: COVID-19 and the South Africa Construction Industry, J. Eng. Des. Technol. 20 (2022) 183–200. https://doi.org/10.1108/jedt-02-2021-0079.
[20] J. Corburn, D. Vlahov, B. Mberu, L. Riley, W.T. Caiaffa, S.F. Rashid, A. Ko, S. Patel, S. Jukur, E. Martínez-Herrera, Slum Health: Arresting COVID-19 and Improving Well-Being in Urban Informal Settlements, J. Urban Health 97 (2020) 348–357. https://doi.org/10.1007/s11524-020-00438-6.
[21] M. Sami Ur Rehman, M.T. Shafiq, M. Afzal, Impact of COVID-19 on Project Performance in the UAE Construction Industry, J. Eng. Des. Technol. 20 (2022) 245–266. https://doi.org/10.1108/jedt-12-2020-0481.
[22] O. Amoo, Y. Lukman, N. Musa, Dispute Resolution Methods Adopted by Contractors During COVID-19 in Eastern Cape South Africa: A Case Study, J. Constr. Bus. Manag. 5 (2022) 54–67. https://doi.org/10.15641/jcbm.5.2.1209.
[23] H. Onyeaka, C.K. Anumudu, Z.T. Al-Sharify, E. Egele-Godswill, P. Mbaegbu, COVID-19 Pandemic: A Review of the Global Lockdown and Its Far-Reaching Effects, Sci. Prog. 104 (2021) 00368504211019854. https://doi.org/10.1177/00368504211019854.
[24] R.A. Waheeb, K.A. Wheib, B.S. Andersen, R. Al-Suhiili, Impact of Pandemic SARS COVID-19 on Different Construction Project Management: Problems and Solutions, Public Works Manag. Policy 28 (2023) 306–338. https://doi.org/10.1177/1087724x221113579.
[25] H.A. Rani, A.M. Farouk, K. Anandh, S. Almutairi, R.A. Rahman, Impact of COVID-19 on Construction Projects: The Case of India, Buildings 12 (2022) 762. https://doi.org/10.3390/buildings12060762.

[26] C.O. Aigbavboa, D.O. Aghimien, W.D. Thwala, M.N. Ngozwana, Unprepared Industry Meet Pandemic: Covid-19 and the South Africa Construction Industry, J. Eng. Des. Technol. 20 (2022) 183–200. https://doi.org/10.1108/jedt-02-2021-0079.
[27] I. Musonda, N. Rakolote, Impact of the COVID-19 Pandemic in the South African Construction Industry, Acta Structilia 29 (2022). https://doi.org/10.18820/24150487/as29i1.6.
[28] O.I. Olanrewaju, N. Chileshe, E.O. Adekunle, C. Salihu, Modelling the Environmental, Economic and Social Impacts of Coronavirus Pandemic on the Construction Industry, Int. J. Constr. Manag. (2022) 1–14. https://doi.org/10.1080/15623599.2022.2120077.
[29] F. Araya, K. Ogalde, L. Sierra, A Critical Review of Impacts from the COVID-19 Pandemic in Construction Projects: What Have We Learned?, in: Constr. Res. Congr. 2024, American Society of Civil Engineers, Des Moines, Iowa, 2024: pp. 621–631. https://doi.org/10.1061/9780784485286.062.
[30] A. Mohsen, W.S. Alaloul, M.S. Liew, M.A. Musarat, A.O. Baarimah, K.M. Alzubi, M. Altaf, Impact of the COVID-19 Pandemic on Construction Industry in Malaysia, in: 2021 Third Int. Sustain. Resil. Conf. Clim. Change, IEEE, Sakheer, Bahrain, 2021: pp. 237–241. https://doi.org/10.1109/IEEECONF53624.2021.9667984.
[31] K.V. Prasad, N. Bhat, Impact of the Covid-19 Pandemic on Construction Organisations in India: A Case Study, Proc. Inst. Civ. Eng. - Civ. Eng. 175 (2022) 17–21. https://doi.org/10.1680/jcien.21.00129.
[32] H. Liang, T. Liu, W. Yang, F. Xia, Impact of COVID-19 Pandemic Perception on Job Stress of Construction Workers, Int. J. Environ. Res. Public. Health 19 (2022) 10169. https://doi.org/10.3390/ijerph191610169.
[33] D. Larasati, N. Ekawati, S. Triyadi, A.F. Muchlis, A. Wardhani, Impact of the Pandemic COVID-19 on the Implementation of Construction Contracts, IOP Conf. Ser. Earth Environ. Sci. 738 (2021) 012075. https://doi.org/10.1088/1755-1315/738/1/012075.
[34] P. Duan, Y.M. Goh, J. Zhou, The Impact of Covid-19 Pandemic on Construction Safety in China and the U.S.: A Comparative Study, Saf. Sci. 161 (2023) 106076. https://doi.org/10.1016/j.ssci.2023.106076.
[35] B. Briggs, C.J. Friedland, I. Nahmens, C. Berryman, Y. Zhu, Industrial construction safety policies and practices with cost impacts in a COVID-19 pandemic environment: A Louisiana DOW case study, J. Loss Prev. Process Ind. 76 (2022) 104723. https://doi.org/10.1016/j.jlp.2021.104723.
[36] N. Quoc Toan, N. Van Tam, Survey data of the COVID-19 pandemic impact on construction workforce: A case of Vietnam, E3S Web Conf. 403 (2023) 02012. https://doi.org/10.1051/e3sconf/202340302012.
[37] K. Krajníková, J. Smetanková, R. Ručinský, P. Mésároš, L. Zemanová, Comparison of the Impacts of the Financial Crisis and the Covid-19 Pandemic Crisis on Selected Financial Indicator of Construction Companies, in: L. Knapčíková, D. Peraković (Eds.), 7th EAI Int. Conf. Manag. Manuf. Syst., Springer International Publishing, Cham, 2023: pp. 197–208. https://doi.org/10.1007/978-3-031-22719-6_15.
[38] A. Bhattacharyya, M. Hastak, Impact Analysis of Covid-19 Pandemic on Construction Employment in the United States, in: S. Walbridge, M. Nik-Bakht, K.T.W. Ng, M. Shome, M.S. Alam, A. El Damatty, G. Lovegrove (Eds.), Proc. Can. Soc. Civ. Eng. Annu. Conf. 2021, Springer Nature Singapore, Singapore, 2023: pp. 411–420. https://doi.org/10.1007/978-981-19-0968-9_33.
[39] M. Nový, J. Nováková, Impact of the COVID-19 Pandemic on Construction Companies in the Czech Republic, Procedia Comput. Sci. 196 (2022) 717–723. https://doi.org/10.1016/j.procs.2021.12.068.

[40] N. Smajlović Orman, A. El Sayed, The Impact of Pandemic on the Survival of Construction Industry: A Case of COVID-19 in Bosnia and Herzegovina, in: N. Ademović, E. Mujčić, Z. Akšamija, J. Kevrić, S. Avdaković, I. Volić (Eds.), Adv. Technol. Syst. Appl. VI, Springer International Publishing, Cham, 2022: pp. 361–373. https://doi.org/10.1007/978-3-030-90055-7_29.
[41] Iffah Sahira Bakeri, Siti Rashidah Hanum Abd Wahab, Adi Irfan Che Ani, The Technology Adaptation Measures to Reduce Impacts of Covid-19 Pandemic on the Construction Industry, J. Adv. Res. Appl. Sci. Eng. Technol. 31 (2023) 34–52. https://doi.org/10.37934/araset.31.1.3452.
[42] M.K.S. Al-Mhdawi, M.P. Brito, B.S. Onggo, H.A. Rashid, Analyzing the Impact of the COVID-19 Pandemic Risks on Construction Projects in Developing Countries: Case of Iraq, in: Constr. Res. Congr. 2022, American Society of Civil Engineers, Arlington, Virginia, 2022: pp. 1013–1023. https://doi.org/10.1061/9780784483961.106.
[43] M. Iqbal, N. Ahmad, M. Waqas, M. Abrar, Covid-19 Pandemic and Construction Industry: Impacts, Emerging Construction Safety Practices, and Proposed Crisis Management, Braz. J. Oper. Prod. Manag. 18 (2021) 1–17. https://doi.org/10.14488/BJOPM.2021.034.
[44] Z.N. Alani, M.N.A. Alshekhly, H. Emad, A.N.J. Al-Tamimi, M. Alfiras, Impact of the Pandemic—Covid-19 on Construction Sector in Bahrain, in: A. Hamdan, E.S. Aldhaen (Eds.), Artif. Intell. Transform. Digit. Mark., Springer Nature Switzerland, Cham, 2024: pp. 617–626. https://doi.org/10.1007/978-3-031-35828-9_52.
[45] C.O. Aigbavboa, D.O. Aghimien, W.D. Thwala, M.N. Ngozwana, Unprepared Industry Meet Pandemic: Covid-19 and the South Africa Construction Industry, J. Eng. Des. Technol. 20 (2022) 183–200. https://doi.org/10.1108/JEDT-02-2021-0079.
[46] M. Salem, R. Kirkham, R. Al-Sabah, S. Chebli, Covid-19 and the Construction Sector: Impacts and an Agenda for Post-Pandemic Policy in the Context of Kuwait, J. Eng. Res. (2023) S2307187723003231. https://doi.org/10.1016/j.jer.2023.11.017.
[47] S. Mohamed Elnaggar, H. Elhegazy, Study the Impact of the Covid-19 Pandemic on the Construction Industry in Egypt, Structures 35 (2022) 1270–1277. https://doi.org/10.1016/j.istruc.2021.09.028.
[48] H.A. Rani, A.M. Farouk, K.S. Anandh, S. Almutairi, R.A. Rahman, Impact of COVID-19 on Construction Projects: The Case of India, Buildings 12 (2022) 762. https://doi.org/10.3390/buildings12060762.
[49] K.P. Kisi, T. Sulbaran, Construction Cost and Schedule Impacts Due to COVID-19, J. Leg. Aff. Dispute Resolut. Eng. Constr. 14 (2022) 04522024. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000565.
[50] N.H.A. Binti Sany Abdillah, N.A. Isnaini Janipha, S.S. Judi, Impacts of COVID-19 Pandemic to the Contractor Organizations in the Construction Industry., IOP Conf. Ser. Earth Environ. Sci. 1067 (2022) 012071. https://doi.org/10.1088/1755-1315/1067/1/012071.
[51] S. Rokooei, A. Alvanchi, M. Rahimi, Perception of Covid-19 Impacts on the Construction Industry Over Time, Cogent Eng. 9 (2022) 2044575. https://doi.org/10.1080/23311916.2022.2044575.
[52] S.Y. Tan, N. Zainon, Impact of Covid-19 Pandemic on the Quantity Surveying Practices in Malaysia, Eng. Constr. Archit. Manag. 30 (2023) 3480–3508. https://doi.org/10.1108/ECAM-11-2021-0988.
[53] F.A. Ghansah, W. Lu, Responses to the Covid-19 Pandemic in the Construction Industry: A Literature Review of Academic Research, Constr. Manag. Econ. 41 (2023) 781–803. https://doi.org/10.1080/01446193.2023.2205159.

[54] A. Calistri, P. Francesco Roggero, G. Palù, Chaos Theory in the Understanding of Covid-19 Pandemic Dynamics, Gene 912 (2024) 148334. https://doi.org/10.1016/j.gene.2024.148334.
[55] K. Popper, The Logic of Scientific Discovery, Repr. 2008 (twice), Routledge, London, 2008.
[56] M. Ogunnusi, M. Hamma-Adama, H. Salman, T. Kouider, Covid-19 Pandemic: The Effects and Prospects in the Construction Industry., Int. J. Real Estate Stud. 14 (2020).
[57] Chisnall, Ladd, Becke, Wilson, The Impact of COVID-19 on Construction Projects | Article | Chambers and Partners, (2020). https://chambers.com/articles/the-impact-of-covid-19-on-construction-projects (accessed May 12, 2024).
[58] M.I. Ermilova, I. Zavrl, Impact of the COVID-19 Pandemic on the Housing and Construction Markets, in: V.S. Osipov (Ed.), Post-COVID Econ. Revival Vol. II, Springer International Publishing, Cham, 2022: pp. 173–185. https://doi.org/10.1007/978-3-030-83566-8_11.
[59] C. Amoah, E. Bamfo-Agyei, F. Simpeh, The Covid-19 Pandemic: The Woes of Small Construction Firms in Ghana, Smart Sustain. Built Environ. 11 (2022) 1099–1115. https://doi.org/10.1108/SASBE-02-2021-0025.
[60] M. Raoufi, A.R. Fayek, Identifying Actions to Control and Mitigate the Effects of the COVID-19 Pandemic on Construction Organizations: Preliminary Findings, Public Works Manag. Policy 26 (2021) 47–55. https://doi.org/10.1177/1087724X20969164.
[61] R. Zhang, L. Chen, X. Sun, The Impact of Covid-19 on the Financial Performance of the UK Construction Firms, Constr. Manag. Econ. (2024) 1–19. https://doi.org/10.1080/01446193.2024.2355882.
[62] R.H. Assaad, I.H. El-adaway, M. Hastak, K. LaScola Needy, The COVID-19 Pandemic: A Catalyst and Accelerator for Offsite Construction Technologies, J. Manag. Eng. 38 (2022) 04022062. https://doi.org/10.1061/(ASCE)ME.1943-5479.0001091.
[63] A. Alsharef, S. Banerjee, S.J. Uddin, A. Albert, E. Jaselskis, Early Impacts of the Covid-19 Pandemic on the United States Construction Industry, Int. J. Environ. Res. Public. Health 18 (2021) 1559. https://doi.org/10.3390/ijerph18041559.
[64] Saunders et al_2023_Research Methods for Business Students.pdf, (n.d.).
[65] F. Castiglione, E. Mancini, M. Pedicini, A.S. Jarrah, Quantitative Modelling Approaches, in: Ref. Module Life Sci., Elsevier, 2024: p. B9780323955027000294. https://doi.org/10.1016/B978-0-323-95502-7.00029-4.
[66] A. Arslan, S. Staub, Theory X and Theory Y Type Leadership Behavior and its Impact on Organizational Performance: Small Business Owners in the Şishane Lighting and Chandelier District, Procedia - Soc. Behav. Sci. 75 (2013) 102–111. https://doi.org/10.1016/j.sbspro.2013.04.012.
[67] M.R. Beauchamp, D. McEwan, K.J. Waldhauser, Team Building: Conceptual, Methodological, and Applied Considerations, Curr. Opin. Psychol. 16 (2017) 114–117. https://doi.org/10.1016/j.copsyc.2017.02.031.
[68] R.J. Moniz, History of Managerial Thought: A Brief Overview, in: Pract. Eff. Manag. Libr., Elsevier, 2010: pp. 1–18. https://doi.org/10.1016/B978-1-84334-578-7.50001-3.
[69] H. Fayol, General and Industrial Management, Martino Publishing ; Pittman Publishing Corp., Mansfield Centre, CT., New York, 2013.
[70] R.A. Thiétart, B. Forgues, Chaos Theory and Organization, Organ. Sci. 6 (1995) 19–31. https://doi.org/10.1287/orsc.6.1.19.
[71] H. Singh, A. Singh, Principles of Complexity and Chaos Theory in Project Execution: A New Approach to Management, Cost Eng. 44 (2002) 23.
[72] G. Williams, Chaos Theory Tamed, CRC Press, 1997.

[73] D. Rickles, P. Hawe, A. Shiell, A Simple Guide to Chaos and Complexity, J. Epidemiol. Community Health 61 (2007) 933–937. https://doi.org/10.1136/jech.2006.054254.
[74] R.-A. Thietart, B. Forgues, Chaos Theory and Organization, Organ. Sci. 6 (1995) 19–31. https://doi.org/10.1287/orsc.6.1.19.
[75] D. Rickles, P. Hawe, A. Shiell, A Simple Guide to Chaos and Complexity, J. Epidemiol. Community Health 61 (2007) 933–937. https://doi.org/10.1136/jech.2006.054254.
[76] S. Agarwal, T.P. Singh, D. Bajaj, V. Pant, Affordable Housing in Urban India: A Review of Critical Success Factors (CSFS) Addressing Housing Adequacy with Affordability for the Urban Poor, Hous. Care Support 25 (2022) 61–79. https://doi.org/10.1108/hcs-08-2021-0022.
[77] Y. Gamil, A.H. Al-Sarafi, T. Najeh, Post Covid-19 Pandemic Possible Business Continuity Strategies for Construction Industry Revival a Preliminary Study in the Malaysian Construction Industry, Int. J. Disaster Resil. Built Environ. 14 (2023) 640–654. https://doi.org/10.1108/IJDRBE-11-2021-0147.
[78] V. Salazar, S. Rodriguez, Impact on the Performance of Construction Projects due to COVID-19, in: 2021 11th Int. Conf. Inf. Commun. Manag., ACM, Tokyo Japan, 2021: pp. 137–141. https://doi.org/10.1145/3484399.3484421.
[79] K. Agyekum, A.S. Kukah, J. Amudjie, The Impact of Covid-19 on the Construction Industry in Ghana: The Case of Some Selected Firms, J. Eng. Des. Technol. 20 (2022) 222–244. https://doi.org/10.1108/JEDT-11-2020-0476.
[80] B.J. Idrovo-Aguirre, J.E. Contreras-Reyes, Monetary Fiscal Contributions to Households and Pension Fund Withdrawals during the COVID-19 Pandemic: An Approximation of Their Impact on Construction Labor Supply in Chile, Soc. Sci. 10 (2021) 417. https://doi.org/10.3390/socsci10110417.
[81] F. Araya, P. Poblete, L.A. Salazar, O. Sánchez, L. Sierra-Varela, Á. Filun, Exploring the Influence of Construction Companies Characteristics on Their Response to the COVID-19 Pandemic in the Chilean Context, Sustainability 16 (2024) 3417. https://doi.org/10.3390/su16083417.
[82] B. Stehlíková, M. Taušová, K. Čulková, Impact of the COVID-19 Pandemic on the Economic Development of the Mining and Construction Industry: Case Study in Slovakia, Economies 12 (2024) 119. https://doi.org/10.3390/economies12050119.
[83] N.H. Najib, S. Ismail, R. Che Amat, S. Durdyev, Z. Konečná, A.G. Chofreh, F.A. Goni, C. Subramaniam, J.J. Klemeš, Stakeholders' Impact Factors of the COVID-19 Pandemic on Sustainable Mixed Development Projects: A Systematic Review and Meta-Analysis, Sustainability 14 (2022) 10418. https://doi.org/10.3390/su141610418.
[84] M.I. Ermilova, I. Zavrl, Impact of the COVID-19 Pandemic on the Housing and Construction Markets, in: V.S. Osipov (Ed.), Post-COVID Econ. Revival Vol. II, Springer International Publishing, Cham, 2022: pp. 173–185. https://doi.org/10.1007/978-3-030-83566-8_11.
[85] F. Jin, W. Xiang, Z. Ji, B. Zhang, Quantifying the Evolutionary Mechanism of Covid-19 Impact on International Construction Multi-Projects: A Risk Driver Perspective, Eng. Constr. Archit. Manag. 30 (2023) 3602–3619. https://doi.org/10.1108/ECAM-10-2021-0887.
[86] F. Jin, W. Xiang, Z. Ji, B. Zhang, Quantifying the Evolutionary Mechanism of Covid-19 Impact on International Construction Multi-Projects: A Risk Driver Perspective, Eng. Constr. Archit. Manag. 30 (2023) 3602–3619. https://doi.org/10.1108/ECAM-10-2021-0887.
[87] B. Amadei, M. Noori, Navigating the Complexity Across the Peace–Sustainability–Climate Security Nexus, 1st ed., CRC Press, Boca Raton, 2023. https://doi.org/10.1201/9781003435006.

[88] M. Aboulnaga, S.E. Helmy, Biomimetic Architecture and Its Role in Developing Sustainable, Regenerative, and Livable Cities: Global Perspectives and Approaches in the Age of COVID-19, Springer International Publishing, Cham, 2022. https://doi.org/10.1007/978-3-031-08292-4.
[89] C. Lu, D. Yu, Q. Luo, C. Xu, A Study of the Effects of Job Stress on the Psychosocial Safety Behavior of Construction Workers: The Mediating Role of Psychological Resilience, Buildings 13 (2023) 1930. https://doi.org/10.3390/buildings13081930.
[90] B. Hartono, A. Nurizzati, Project Team Resilience During Pandemic: Evidence from the Indonesian Construction Industry, in: 2023 IEEE Int. Conf. Ind. Eng. Eng. Manag. IEEM, IEEE, Singapore, Singapore, 2023: pp. 1713–1717. https://doi.org/10.1109/IEEM58616.2023.10406389.
[91] A. Sanlı, P.I. Cakmak, Developing Resilient Construction Professionals in the Covid-19 Era, in: Constr. Saf. Health Well- COVID-19 Era, 1st ed., Routledge, London, 2023: pp. 200–212. https://doi.org/10.1201/9781003278368-17.
[92] N. Borg, C.M. Scott-Young, N. Naderpajouh, J. Borg, Surviving Adversity: Personal and Career Resilience in the Aec Industry During the Covid-19 Pandemic, Constr. Manag. Econ. 41 (2023) 361–378. https://doi.org/10.1080/01446193.2022.2096250.
[93] J.E. Velázquez-Diaz, P. Gosain, N.E. Ganapati, L. Zhang, Understanding COVID-19's Impacts on Multisector Stakeholder Values on Housing Resilience, in: Constr. Res. Congr. 2022, American Society of Civil Engineers, Arlington, Virginia, 2022: pp. 396–405. https://doi.org/10.1061/9780784483954.041.
[94] M. Salem, R. Kirkham, R. Al-Sabah, S. Chebli, Covid-19 and the Construction Sector: Impacts and an Agenda for Post-Pandemic Policy in the Context of Kuwait, J. Eng. Res. (2023) S2307187723003231. https://doi.org/10.1016/j.jer.2023.11.017.
[95] N. Adepu, S. Kermanshachi, A. Pamidimukkala, Analyzing COVID-19 Mitigation Strategies in the Construction Industry, in: Int. Conf. Transp. Dev. 2024, American Society of Civil Engineers, Atlanta, Georgia, 2024: pp. 421–430. https://doi.org/10.1061/9780784485521.038.
[96] F. Simpeh, C. Amoah, Covid-19 Guidelines Incorporated in the Health and Safety Management Policies of Construction Firms, J. Eng. Des. Technol. 20 (2022) 6–23. https://doi.org/10.1108/jedt-01-2021-0042.
[97] R. Selleck, M. Cattani, M. Hassall, How Did COVID-19 Pandemic Impact Safety Performance on a Construction Project? A Case Study Comparing Pre and Post COVID-19 Influence on Safety at an Australian Construction Site, Safety 8 (2022) 77. https://doi.org/10.3390/safety8040077.
[98] W. Lu, L. Wu, J. Xu, J. Lou, Construction E-Inspection 2.0 in the COVID-19 Pandemic Era: A Blockchain-Based Technical Solution, J. Manag. Eng. 38 (2022) 04022032. https://doi.org/10.1061/(ASCE)ME.1943-5479.0001063.
[99] Y.T. Kum, J.B.H. Yap, Y.-L. Lew, W.P. Lee, Transforming construction health and safety management during COVID-19 pandemic using innovative technologies: PLS-SEM approach, Eng. Constr. Archit. Manag. 31 (2024) 2770–2808. https://doi.org/10.1108/ECAM-08-2022-0780.
[100] M.K.S. Al-Mhdawi, M.P. Brito, M. Abdul Nabi, I.H. El-adaway, B.S. Onggo, Capturing the Impact of COVID-19 on Construction Projects in Developing Countries: A Case Study of Iraq, J. Manag. Eng. 38 (2022) 05021015. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000991.
[101] V. Leontie, L.-G. Maha, I.C. Stoian, COVID-19 Pandemic and Its Effects on the Usage of Information Technologies in the Construction Industry: The Case of Romania, Buildings 12 (2022) 166. https://doi.org/10.3390/buildings12020166.

[102] S. Onyshchenko, A. Hlushko, O. Maslii, V. Skryl, Risks and Threats to Economic Security of Enterprises in the Construction Industry Under Pandemic Conditions, in: V. Onyshchenko, G. Mammadova, S. Sivitska, A. Gasimov (Eds.), Proc. 3rd Int. Conf. Build. Innov., Springer International Publishing, Cham, 2022: pp. 711–724. https://doi.org/10.1007/978-3-030-85043-2_66.
[103] G.B. Fernandez, I.M. Ccoyllar-Escobar, A.E. Huaccha-Uriol, A.N. Vilca-Fanola, A.A. Erazo-Rondinel, A review of the implementation of Lean Construction tools during the Covid-19 pandemic, in: 2023 Congr. Int. Innov. Tend. En Ing. CONIITI, IEEE, Bogotá, Colombia, 2023: pp. 1–5. https://doi.org/10.1109/CONIITI61170.2023.10324127.
[104] D. Settembre-Blundo, R. González-Sánchez, S. Medina-Salgado, F.E. García-Muiña, Flexibility and Resilience in Corporate Decision Making: A New Sustainability-Based Risk Management System in Uncertain Times, Glob. J. Flex. Syst. Manag. 22 (2021) 107–132. https://doi.org/10.1007/s40171-021-00277-7.
[105] F.Y.Y. Ling, J.Y. Tam, Agility of Facilities Management Organizations During the Covid-19 Pandemic: Lessons Learnt for Future Pandemics, Facilities 40 (2022) 862–878. https://doi.org/10.1108/F-02-2022-0032.
[106] B. Mokline, M.A. Ben Abdallah, The Mechanisms of Collective Resilience in a Crisis Context: The Case of the 'Covid-19' Crisis, Glob. J. Flex. Syst. Manag. 23 (2022) 151–163. https://doi.org/10.1007/s40171-021-00293-7.
[107] P.G. Northouse, Leadership: Theory and Practice, Sage publications, 2021.
[108] A.H. Maslow, A Theory of Human Motivation, Dancing Unicorn Books, Lanham, 2017.
[109] M. Eisend, A. Kuß, Research Methodology in Marketing: Theory Development, Empirical Approaches and Philosophy of Science Considerations, Springer, Cham, Switzerland, 2019. https://doi.org/10.1007/978-3-030-10794-9.
[110] T.A.N. Alenezi, Covid-19 Causes of Delays on Construction Projects in Kuwait, Int. J. Eng. Res. Gen. Sci. 8 (2020) 6–9.
[111] P.O. Kukoyi, F. Simpeh, O.J. Adebowale, J.N. Agumba, Managing the Risk and Challenges of Covid-19 on Construction Sites in Lagos, Nigeria, J. Eng. Des. Technol. 20 (2022) 99–144. https://doi.org/10.1108/JEDT-01-2021-0058.
[112] Z. Wang, X. Cai, Z. Liu, Survival and Revival: Transition Path of the Chinese Construction Industry During the COVID-19 Pandemic, Eng. Manag. J. 35 (2023) 333–345. https://doi.org/10.1080/10429247.2022.2108670.
[113] N. Myers, T.E. Thornton, Accountability, Polarization, and Federalism: Oversight During and After the Covid-19 Pandemic*, J. Emerg. Manag. 19 (2021) 49–58. https://doi.org/10.5055/jem.0613.
[114] C. De Villiers, D. Cerbone, W. Van Zijl, The South African Government's Response to Covid-19, J. Public Budg. Account. Financ. Manag. 32 (2020) 797–811. https://doi.org/10.1108/jpbafm-07-2020-0120.
[115] K. Matebese-Notshulwana, Weak Procurement Practices and the Challenges of Service Delivery in South Africa, in: N. Dorasamy, O. Fagbadebo (Eds.), Public Procure. Corrupt. Crisis Gov. Afr., Springer International Publishing, Cham, 2021: pp. 93–111. https://doi.org/10.1007/978-3-030-63857-3_6.
[116] S. Berge, H. Von Blottnitz, An Estimate of Construction and Demolition Waste Quantities and Composition Expected in South Africa, South Afr. J. Sci. (2022). https://doi.org/10.17159/sajs.2022/12485.
[117] C. Amoah, F. Simpeh, Implementation challenges of COVID-19 safety measures at construction sites in South Africa, J. Facil. Manag. 19 (2021) 111–128. https://doi.org/10.1108/jfm-08-2020-0061.
[118] Y. Olum, Modern Management Theories and Practices, Uganda Makerere Univ. (2004) 1–24.

[119] A. Shibani, D.H. Hassan, N.S. Shakir, The Effects of Pandemic on Construction Industry in the Uk, Mediterr. J. Soc. Sci. 11 (2020). https://doi.org/10.36941/mjss-2020-0063.
[120] G.S. Goda, E.J. Soltas, The Impacts of Covid-19 Illnesses on Workers, National Bureau of Economic Research, 2022.
[121] J. Bell, H. Chan, M. Chan, S. Moon, COVID-19 and Construction: Impact Analysis on Construction Performance during Two Infection Waves in Victoria, Australia, Sustainability 14 (2022) 2580. https://doi.org/10.3390/su14052580.
[122] R.R. Gohunuwatta, H.A.H.P. Perera, A.K.S. Perera, P.A.P.V.D.S. Disaratna, Effect of COVID-19 pandemic on the productivity of construction projects in Sri Lanka, ITU Press Press Istanb. Tech. Univ. (2024) 1. https://doi.org/10.58278/0.2024.32.
[123] N. Adepu, S. Kermanshachi, A. Pamidimukkala, K. Loganathan, Evaluation of Challenges to the Construction Industry's Project Efficiency Caused by the COVID-19 Pandemic, in: Int. Conf. Transp. Dev. 2023, American Society of Civil Engineers, Austin, Texas, 2023: pp. 674–682. https://doi.org/10.1061/9780784484883.058.
[124] B. Wormuth, S. Wang, P. Dehghanian, M. Barati, A. Estebsari, T.P. Filomena, M.H. Kapourchali, M.A. Lejeune, Electric Power Grids Under High-Absenteeism Pandemics: History, Context, Response, and Opportunities, IEEE Access 8 (2020) 215727–215747. https://doi.org/10.1109/ACCESS.2020.3041247.
[125] M. Awada, B. Becerik-Gerber, E. White, S. Hoque, Z. O'Neill, G. Pedrielli, J. Wen, T. Wu, Occupant Health in Buildings: Impact of the Covid-19 Pandemic on the Opinions of Building Professionals and Implications on Research, Build. Environ. 207 (2022) 108440. https://doi.org/10.1016/j.buildenv.2021.108440.
[126] H.A. Rani, A.M. Farouk, K. Anandh, S. Almutairi, R.A. Rahman, Impact of Covid-19 on Construction Projects: The Case of India, Buildings 12 (2022) 762. https://doi.org/10.3390/buildings12060762.
[127] S.H. Zamani, R.A. Rahman, M.A. Fauzi, L. Mohamed Yusof, Government Pandemic Response Strategies for AEC Enterprises: Lessons from Covid-19, J. Eng. Des. Technol. 22 (2024) 690–717. https://doi.org/10.1108/JEDT-10-2021-0540.
[128] M. Grida, R. Mohamed, A.N.H. Zaied, Evaluate the Impact of Covid-19 Prevention Policies on Supply Chain Aspects Under Uncertainty, Transp. Res. Interdiscip. Perspect. 8 (2020) 100240. https://doi.org/10.1016/j.trip.2020.100240.
[129] W.H. Gan, D. Koh, Covid-19 and Return-to-Work for the Construction Sector: Lessons from Singapore, Saf. Health Work 12 (2021) 277–281. https://doi.org/10.1016/j.shaw.2021.04.001.
[130] F.A. Ghansah, W. Lu, Responses to the Covid-19 Pandemic in the Construction Industry: A Literature Review of Academic Research, Constr. Manag. Econ. 41 (2023) 781–803. https://doi.org/10.1080/01446193.2023.2205159.
[131] C. Zhang, W. Hu, Y. Li, Y. Lv, S. Zhang, Impact of the Covid-19 Pandemic on Routine Vaccination Services in Shaanxi Province, Northwest China: Non-Pharmaceutical Intervention Period and Mass Covid-19 Vaccination Period, Hum. Vaccines Immunother. 19 (2023) 2251826. https://doi.org/10.1080/21645515.2023.2251826.
[132] Z. Cao, R. Yu, Q. Yuan, W. Ji, X. Li, P. Gao, L. Miao, X. Wen, L. Suo, Impact of the Covid-19 Pandemic on Routine Vaccination Coverage Under Varying Prevalence Conditions: A Cohort Study in Beijing, China, Vaccine 42 (2024) 213–219. https://doi.org/10.1016/j.vaccine.2023.12.014.
[133] M. Ayat, A. Ullah, C.W. Kang, Impact of the Coronavirus disease 2019 and the post-pandemic construction sector (Pakistan), Int. J. Manag. Proj. Bus. 15 (2022) 659–675. https://doi.org/10.1108/IJMPB-11-2020-0349.

[134] Iffah Sahira Bakeri, Siti Rashidah Hanum Abd Wahab, Adi Irfan Che Ani, The Technology Adaptation Measures to Reduce Impacts of Covid-19 Pandemic on the Construction Industry, J. Adv. Res. Appl. Sci. Eng. Technol. 31 (2023) 34–52. https://doi.org/10.37934/araset.31.1.3452.

[135] O.I. Olanrewaju, N. Chileshe, E.O. Adekunle, C. Salihu, Modelling the Environmental, Economic and Social Impacts of Coronavirus Pandemic on the Construction Industry, Int. J. Constr. Manag. (2022) 1–14. https://doi.org/10.1080/15623599.2022.2120077.

[136] M. Muneer, N. Khan, M. Awais Hussain, Z. Shuai, A.A. Khan, R. Farooq, M.A. Moawwez, M.A.U.R. Tariq, A Quantitative Study of the Impact of Organizational Culture, Communication Management, and Clarity in Project Scope on Constructions' Project Success with Moderating Role of Project Manager's Competencies to Enhance Constructions Management Practices, Buildings 12 (2022) 1856. https://doi.org/10.3390/buildings12111856.

[137] M.B. Esa, F.S.B. Ibrahim, E.B.M. Kamal, Covid-19 Pandemic Lockdown: The Consequences Towards Project Success in Malaysian Construction Industry, Adv. Sci. Technol. Eng. Syst. J. 5 (2020) 973–983. https://doi.org/10.25046/aj0505119.

[138] A. Artpairin, S. Pinmanee, Critical Success Factors in the Management of Petrochemical Construction Projects for Contractors and Subcontractors During the Covid-19 Pandemic, Int. J. Constr. Manag. 23 (2023) 1956–1968. https://doi.org/10.1080/15623599.2022.2029678.

[139] M.A. Kassem, A.R. Radzi, A. Pradeep, M. Algahtany, R.A. Rahman, Impacts and Response Strategies of the COVID-19 Pandemic on the Construction Industry Using Structural Equation Modeling, Sustainability 15 (2023) 2672. https://doi.org/10.3390/su15032672.

[140] M.N.K. Saunders, P. Lewis, A. Thornhill, Research Methods for Business Students, Ninth edition, Pearson, Harlow, England ; New York, 2023.

[141] C. Andrade, The Inconvenient Truth About Convenience and Purposive Samples, Indian J. Psychol. Med. 43 (2021) 86–88. https://doi.org/10.1177/0253717620977000.

[142] W.E. Saris, Design, Evaluation, and Analysis of Questionnaires for Survey Research, Second Edition, Wiley, Hoboken, New Jersey, 2014.

[143] J. Trusty, B. Thompson, J.V. Petrocelli, Practical Guide for Reporting Effect Size in Quantitative Research in the Journal of Counseling & Development, J. Couns. Dev. 82 (2004) 107–110. https://doi.org/10.1002/j.1556-6678.2004.tb00291.x.

[144] J. Jonker, B. Pennink, The Essence of Research Methodology: A Concise Guide for Master and PhD Students in Management Science, Springer Berlin Heidelberg, Berlin, Heidelberg, 2009. https://doi.org/10.1007/978-3-540-71659-4.

[145] Y. Gamil, A. Alhagar, The Impact of Pandemic Crisis on the Survival of Construction Industry: A Case of Covid-19, Mediterr. J. Soc. Sci. 11 (2020) 122–122. https://doi.org/10.36941/mjss-2020-0047.

[146] A.P. Field, Discovering Statistics Using IBM SPSS Statistics: and Sex and Drugs and Rock "N" Roll, 4th edition, Sage, Los Angeles, 2013.

[147] CIDB, Requirements for Grading | CIDB, (2021). https://www.cidb.org.za/contractors/register-of-contractors/requirements-for-grading/ (accessed September 18, 2023).

[148] F. Ahlemann, F. El Arbi, M.G. Kaiser, A. Heck, A Process Framework for Theoretically Grounded Prescriptive Research in the Project Management Field, Int. J. Proj. Manag. 31 (2013) 43–56. https://doi.org/10.1016/j.ijproman.2012.03.008.

[149] A.P. Field, Discovering Statistics Using IBM SPSS Statistics, 5th edition, SAGE Publications, London, 2018.

[150] J. Pallant, Spss Survival Manual: A Step by Step Guide to Data Analysis Using IBM SPSS, McGraw-hill education (UK), 2020.
[151] J. Stevens, Applied Multivariate Statistics for the Social Sciences, Lawrence Erlbaum Associates Mahwah, NJ, 2002.
[152] S. Stiles, D. Golightly, B. Ryan, Impact of Covid-19 on Health and Safety in the Construction Sector, Hum. Factors Ergon. Manuf. Serv. Ind. 31 (2021) 425–437. https://doi.org/10.1002/hfm.20882.
[153] R. Likert, A Technique for the Measurement of Attitudes., Arch. Psychol. (1932).
[154] A. Joshi, S. Kale, S. Chandel, D.K. Pal, Likert Scale: Explored and Explained, Br. J. Appl. Sci. Technol. 7 (2015) 396–403. https://doi.org/10.9734/bjast/2015/14975.
[155] L. Maseko, D. Root, V. Senthilkumar, Conceptual Framework for Collaborative Risk Management During the Design Phase of Green Building Projects Using DSM, in: Lehrstuhl für Produktentwicklung und Leichtbau, Italy, 2018: pp. 023–032.
[156] M. Weaich, Mapping the Novel Nexus of Young People, Digitalisation, and Sustainability in the Global South: A Bibliometric Approach to Reviewing Literature for Future Studies, (2024). https://doi.org/10.31235/osf.io/b6fmr.
[157] M. Weaich, Exploring the Transdisciplinary Nexus of Young People's Future Livelihoods and Relational Well-Being: A Bibliometric Approach, (2024). https://doi.org/10.31235/osf.io/fhng9.
[158] CIDB, Register of Contractors Overview | CIDB, (2021). https://www.cidb.org.za/contractors/register-of-contractors/overview/ (accessed April 3, 2024).
[159] Department of National Treasury, Frequently Asked Questions and Generic Answers - Preferential Procurement Regulations 2022, (2022). http://ocpo.treasury.gov.za/Resource_Centre/Documents/Frequently%20asked%20Questions%20and%20Generic%20%20Answers%20-%20Preferential%20Procurement%20Regulations%202022%20v1-1.pdf (accessed March 4, 2024).
[160] The Business Times, Construction to Suffer Double-Digit Knockdown from Covid-19 Pandemic, Bus. Times (2020). https://www.businesstimes.com.sg/international/construction-suffer-double-digit-knockdown-covid-19-pandemic (accessed April 3, 2024).
[161] R. Jayathilaka, K. Waidyasekara, Contractual Implications Related to the Construction Industry in Pandemic Situations: A Review of Case Laws., (2022). https://doi.org/10.31705/wcs.2022.21.
[162] A. Olanrewaju, A. AbdulAziz, C.N. Preece, K. Shobowale, Evaluation of Measures to Prevent the Spread of Covid-19 on the Construction Sites, Clean. Eng. Technol. 5 (2021) 100277. https://doi.org/10.1016/j.clet.2021.100277.
[163] D. Gijzel, M. Bosch-Rekveldt, D. Schraven, M. Hertogh, Integrating Sustainability into Major Infrastructure Projects: Four Perspectives on Sustainable Tunnel Development, Sustain. Switz. 12 (2020) 1–18. https://doi.org/10.3390/SU12010006.
[164] E.-A. Attia, A. Alarjani, M.S. Uddin, A.F. Kineber, Determining the Stationary Enablers of Resilient and Sustainable Supply Chains, Sustain. Switz. 15 (2023). https://doi.org/10.3390/su15043461.
[165] M. Cysek-Pawlak, S. Krzysztofik, A. Makowski, Urban Regeneration and Urban Resilience Planning Through Connectivity: The Importance of This Principle of New Urbanism, Eur. Spat. Res. Policy 29 (2022) 111–133. https://doi.org/10.18778/1231-1952.29.1.06.
[166] S. Meerow, P. Pajouhesh, T.R. Miller, Social Equity in Urban Resilience Planning, Local Environ. 24 (2019) 793–808. https://doi.org/10.1080/13549839.2019.1645103.

[167] M.O. Wright, A.S. Masten, A.J. Narayan, Resilience Processes in Development: Four Waves of Research on Positive Adaptation in the Context of Adversity, in: Handb. Resil. Child., Springer, 2012: pp. 15–37.
[168] A. Lavell, C. McFarlane, H.L. Moore, S. Woodcraft, C. Yap, Pathways to Urban Equality through the Sustainable Development Goals: Modes of Extreme Poverty, Resilience, and Prosperity, Int. J. Urban Sustain. Dev. 15 (2023) 215–229. https://doi.org/10.1080/19463138.2023.2226099.
[169] P. Simbanegavi, M. Weaich, K. Ijasan, D. Ahadzie, Y. Adewunmi, Strategic Partnerships and Green Innovations: A Roadmap for Sustainable Co-Value Investment Mixed-Income Housing in South Africa, (2024). https://doi.org/10.31224/3690.
[170] G. Narayanamurthy, G. Tortorella, Impact of Covid-19 Outbreak on Employee Performance – Moderating Role of Industry 4.0 Base Technologies, Int. J. Prod. Econ. 234 (2021) 108075. https://doi.org/10.1016/j.ijpe.2021.108075.
[171] H. Yan, J. Feng, X. Chen, Prediction of the Normalized COVID-19 Epidemic Prevention Costs of Construction Projects Based on an Optimized Neural Network, Math. Probl. Eng. 2022 (2022) 1–13. https://doi.org/10.1155/2022/9015602.
[172] C. Arndt, R. Davies, S. Gabriel, L. Harris, K. Makrelov, B. Modise, S. Robinson, W. Simbanegavi, D. Van Seventer, L. Anderson, Impact of Covid-19 on the South African economy, South. Afr.- Incl. Econ. Dev. Work. Pap. 111 (2020) 1–37.