

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

Nomsa Chabalala¹, Malcolm Weaich², Prisca Simbanegavi³, Pride Ndlovu⁴, Faranani Gethe⁵

¹ School of Construction Economics and Management, University of Witwatersrand, nchabalala97@gmail.com

² School of Construction Economics and Management, University of Witwatersrand, malcolm.weaich@wits.ac.za

³ School of Construction Economics and Management, University of Witwatersrand, prisca.simbanegavi@wits.ac.za

⁴ School of Construction Economics and Management, University of Witwatersrand, pride.ndlovu@wits.ac.za

⁵ School of Construction Economics and Management, University of Witwatersrand, faranani.gethe@wits.ac.za

Abstract

Design/Methodology/Approach: This study employs a quantitative methodology using a cross-sectional survey design. Data were collected from construction industry professionals across South Africa through online questionnaires. The analysis utilises a linear regression model to examine the impact of skilled labour reduction on project turnaround times and the applicability of the Adaptive Chaos Management Theory in Construction (ACMTC).

Purpose: The study explored the impact of workforce reduction, specifically skilled labour, on project turnaround times in the South African construction industry during the COVID-19 pandemic. It also assesses the effectiveness of current project management strategies and the potential of ACMTC to enhance resilience and adaptability.

Findings: Findings indicate that reductions in skilled labour significantly delay project completions. The study also reveals inadequacies in current management strategies to handle the disruptions caused by the pandemic. Furthermore, ACMTC showed potential in improving project resilience and management effectiveness during disruptions.

Research Limitations/Implications: Longitudinal studies are recommended to track changes over time. Also, qualitative insights could enrich the understanding of ACMTC's practical implementation.

Practical Implications: The study underscores the need for construction industry stakeholders to revise management strategies and integrate adaptable theoretical models like ACMTC to better handle future disruptions, ensuring project continuity and efficiency.

Social Implications: By improving project management practices, the construction industry can better sustain employment and project delivery during crises, contributing to economic stability and worker welfare.

Originality/Value: This research contributes to academic and practical fields by empirically testing the Adaptive Chaos Management Theory in a real-world setting and highlighting its

relevance in crisis scenarios, offering a novel approach to managing construction projects during pandemics.

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

Article type: Full length conceptual research paper (9,460), this submission does not relate to a conference or a special issue but does relate to the completion of an MSc at the University of Witwatersrand (First Author). The word count excludes title, author names and affiliations, keywords, highlights, abbreviations, funding, acknowledgments, conflict of interest, data availability statement and references.

Highlights

- COVID-19 interventions prompt significant workforce reduction in South Africa's construction industry.
- Quarantine measures identified as the leading cause of workforce loss.
- Skilled worker reduction critically delays project completion timelines.
- Study underscores need for strategic pandemic recovery plans in construction.
- Recommendations for future research include broader data collection, involving entities like the Construction Industry Development Board.

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

"Hypotheses are nets: only he who casts will catch - Friedrich von Hardenberg, known as Novalis, poignantly captures the essence of intellectual pursuit. This profound statement underscores the significance of theory development, both as a metaphysical exploration and a means to make sense of observable phenomena. It is through the weaving and casting of these 'nets' - the hypotheses - that we gather insights, whether they pertain to the tangible world around us or the more elusive abstract dimensions of reality. Novalis, in his time, highlighted this timeless truth: that the quest for understanding is an active, dynamic process requiring not just the creation but also the courageous deployment of theories to unravel the mysteries of both the seen and the unseen." - [1,2]

Pandemics' Long-Term Impact on Humanity and Construction

Throughout history, outbreaks of contagious illnesses have exerted substantial and enduring consequences on humanity, significantly affecting the construction sector [3-6]. These outbreaks have profoundly influenced the economic, political, and social dimensions of human civilisation, with their effects enduring for centuries [7-10]. Examples include the 1918 H1N1 (Spanish Flu), the 2009 A/H1N1 (Swine Flu) subtype of Influenza A, and the 2019 COVID-19 pandemic caused by SARS-CoV-2 [11-15]. The impact of such diseases on global activities, including construction, has prompted event studies like the present one [12,14,15]. Event studies enable researchers to examine the effects of specific events at

particular times, as demonstrated in this case with the construction industry during the height of COVID-19 [11,15,16].

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

COVID-19 intensified existing delays within the construction industry, significantly affecting project completion times [17-20]. Consequently, restrictions on movement and interpersonal interactions were imposed with restrictions primarily enforced through lockdown measures, with each level varying in terms of restrictiveness on people's movement and interaction [15,21,22]. COVID-19 restrictions disrupted the execution of construction projects, resulting in missed milestones and deadlines [23-25]. Consequently, disruptions at construction sites were anticipated to affect project turnaround times, with COVID-19 expected to cause job losses in the short, medium, and long term [26-28]. The virus was also expected to lead to revenue losses, economic downturns, and business disruptions within the South African building and construction industry [29,30]. It was concluded that workforce reductions resulted in many construction projects failing to achieve their milestones as scheduled, however, due to novelty of the pandemic, a theory explaining the observed phenomenon seems to be void from epistemology.

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

While considerable research has documented the impacts of pandemics on various industries, the specific effects of COVID-19 on the construction sector, particularly in the context of South Africa, remain underexplored. Previous studies have predominantly focused on immediate operational disruptions and generic economic impacts, with less attention given to the intricate dynamics of workforce reduction and its consequential effects on project completion times within the construction industry. This oversight is significant given the critical role of skilled labour in maintaining project timelines and ensuring economic stability within the sector. The existing literature has often overlooked the nuanced interplay between workforce availability and project management strategies during unprecedented global health crises. The application of theoretical frameworks to empirically analyse these dynamics is scant. This gap underscores a pressing need for detailed empirical investigations that not only bridge these knowledge disparities but also enhance the theoretical understanding of crisis management in construction through the development of a new theory to explain the phenomenon. This study aims to fill this gap by providing comprehensive insights into how minor reductions in skilled labour can lead to disproportionately large delays in project completions, thus offering a deeper understanding of the sector's vulnerabilities and resilience strategies in the face of pandemics. This gap in knowledge and practice necessitates a re-evaluation of current management frameworks and the development of more resilient strategies capable of withstanding such disruptions.

Problem Statement: Skilled Labour'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 labour for maintaining project timelines. Despite the recognition of labour as a pivotal element in construction management, there is a paucity of focused research on how reductions in the workforce, particularly skilled labour, 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. The problem is compounded by the fact that traditional project management

strategies may not be adequately equipped to handle the abrupt and unpredictable disruptions caused by pandemics. Existing models and theories often fail to account for the non-linear impacts of small changes in workforce availability on project outcomes. An investigation pertaining to the specific impacts of COVID-19-induced workforce reductions on the completion times of construction projects in South Africa is required.

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 labour 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) 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.

Main Research Question: Skilled Labour Reduction and Management Theory

MRQ: How does the reduction of skilled labour 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?

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:

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

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?

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?

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:

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

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

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.

Research Assumptions: Workforce Impact and Management Strategies

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

Workforce Reductions Directly Impact Project Turnaround Times

The study assumes that reductions in the skilled workforce, as a result of 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 labour is critical to maintaining project timelines and that any reduction would naturally lead to delays.

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 effectively manage the disruptions caused by sudden and significant workforce reductions during a pandemic. This assumption suggests that there is a gap in current management practices that could be addressed through the application of new theoretical approaches like ACMTC.

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

This assumption posits that the principles of the 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.

Research Hypotheses: Skilled Labour, 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:

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

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 the 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.

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

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

Given that COVID-19 intensified pre-existing delays in the construction industry, the built environment adopted measures to mitigate further project completion delays [31,32]. 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 [33]. 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, including the University of the Witwatersrand Research Database and Google Scholar, 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 and authoritative websites. 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.

Theoretical Literature Review

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. 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. H. Singh & A. Singh highlighted Chaos Theory as pivotal for articulating the complexities of Construction Project Management, given its focus on the inherent unpredictability in budgeting, profitability, linear analysis, and strategic planning [34]. 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 [35].

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. 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 [36], challenges traditional models that aim to explain phenomena through regularity, equilibrium, stability, and predictability. It asserts that outcomes are not always directly proportional to their

inputs [37], illustrating how minor alterations can result in substantial system-wide changes, a principle often observed in intervention research. 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. This study, 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.

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 formalise the Adaptive Chaos Management Theory in Construction (ACMTC) [2]:

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 [36].

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 [37].

Adaptability and Resilience in the Face of Chaos

Drawing from Chaos Theory, this tenet emphasises 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 [37].

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, labour practices, and safety protocols that could lead to improved efficiency and resilience against future disruptions [36].

Proving Adaptive Chaos Management Theory in Construction

The successful application of the Adaptive Chaos Management Theory in Construction (ACMTC) within the context of the COVID-19 pandemic has significantly advanced our 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 this tenet, 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. This tenet has proven essential in fostering a strategic approach to managing unforeseeable shifts in the construction landscape. The "butterfly effect" of initial conditions—such as early responses to the pandemic—has had profound and varied impacts on project outcomes [36]. 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. This tenet has highlighted the importance of meticulous planning and response strategies at the earliest stages of a crisis. 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. This adaptability has been key to sustaining operations and minimising 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, labour 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. 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. Each tenet has been validated through empirical evidence and practical application, affirming the theory's value and applicability. 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.

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



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 conceptualised 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 analyses 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, catalyse significant ripple effects across project outcomes, affirming the “butterfly effect” described in Chaos Theory [36]. 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. The research advocates that proactive adaptation and the implementation of flexible management strategies can mitigate the adverse effects of such disruptions. 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. 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.

2.6 Empirical Literature Review

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 [38]. This empirical literature review seeks to delve 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. By drawing on a wide range of studies from 2019 to 2024, this review synthesises 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 labour forces. By analysing 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. 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.

2.6.1 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 [39]. In an effort 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 [40]. 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. However, the literature appears to overlook or underemphasise the consequences these interventions have had on the construction sector.

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

COVID-19 necessitated varied interventions across countries to mitigate delays in their construction industries. 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 sanitisation, and daily temperature checks at entry and exit points [15]. 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 [41]. The majority of South African construction projects adopted guidelines addressing site access, induction processes, management of COVID-19 cases, and social distancing practices [38]. 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. However, empirical evidence suggests that the analytical phase is often overlooked in practice, especially when initial plans falter [42]. Shibani, Hassan & Shakir highlighted the paradox where shift work, intended to minimise COVID-19 transmission among workers, inadvertently led to project delays due to reduced manpower [43]. This literature review thus underscores the significance and methodology of the current study, emphasising its necessity and relevance.

2.6.3 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 [44]. Rani et al. highlighted that even when construction site processes proceed smoothly, projects can still encounter setbacks if issues arise with lower-tier subcontractors and suppliers [45]. 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 [46]. 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.

2.6.4 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 [40]. This literature review underscores the pivotal role of adept management in ensuring project success, especially in the face of unforeseen events like the COVID-19 pandemic [42]. It commences with an overview of the construction industry, detailing the delays induced by COVID-19. Subsequently, the review explores the interventions devised to mitigate these delays, aligning with the objectives of this study. It delves into the global response to workforce reduction and the measures adopted on construction sites to counteract the pandemic's effects. Furthermore, the review examines the impact of these interventions on project turnaround times, directly informing the research question. Employing Chaos Theory, which posits that outcomes are not directly proportional to inputs, the study advises caution in the implementation of interventions, reflecting the unpredictable nature of COVID-19's effects across various sectors, including construction [37]. This unpredictability, emblematic of Chaos Theory, suggests that minor changes can have profound systemic impacts. Nevertheless, not all interventions are deemed counterproductive. For instance, Shibani et al. illustrated how shift work, 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 [43].

2.7 Adapting Construction Management to Global Pandemics: Insights and Strategies

This empirical literature review has elucidated the extensive and varied impacts of the COVID-19 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 has aptly demonstrated how small changes in initial conditions can lead to significant impacts on project outcomes, emphasising 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

A Positivist Philosophy by Quantitative Design

Adhering to the Positivist Research Philosophy, this study prioritised unbiased fact-gathering, uninfluenced by subjective interpretation. It employed a deductive approach for theoretical generalisation of the data collected. Utilising 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 [47]. Purposive sampling selected a representative cohort of participants from the South African construction industry to enhance the study's generalisability, mirroring the broader sub-population. The sample was used as a reflection of the sub-population from which participants were drawn [48]. This research specifically targeted contractors, leveraging their expertise to achieve the study's objectives.

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 [49,50]. Selection was randomised to mitigate bias, prioritising 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 [51]. 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 emphasising that questionnaire submission constituted consent to participate [47]. The survey, conducted from March 2020—marking the onset of the COVID-19 pandemic—was designed to be completed within 10 to 15 minutes [52], ultimately garnering 62 responses.

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

Survey data were analysed using the Statistical Package for Social Sciences (SPSS) via a linear regression model [53]. 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 [54]; project size; and the initiation date of the projects [55]. This categorisation 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 [56,57]. 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 [49].

Statistical Analysis of Workforce Reduction Impact on Project Timelines

The study's data was analysed utilising 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

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. The participation of 62 individuals exceeded the threshold for robust findings, aligning with [58]'s 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 categorised 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 %
	<R1 000 000	9	14.5	14.5	14.5

What was the contract amount you were working on during COVID-19?	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.

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.

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.

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.

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 labour 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 labour 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 [59].

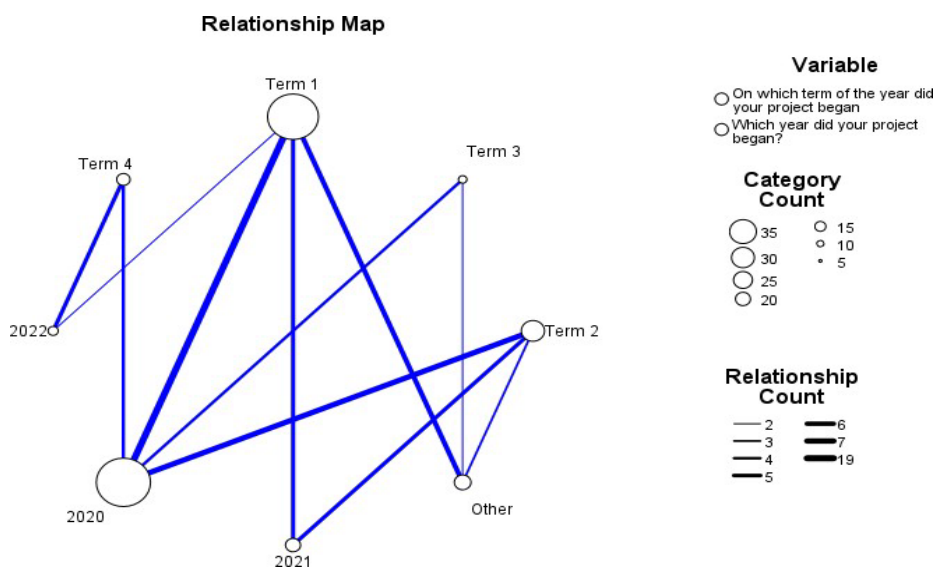


Figure 2: The Relationship Between the Year and Term Construction Projects Began.

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.

Project Start Timeline Relationship Map

This map is essential for visualising 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 are crucial

for evaluating the impact of skilled labour reductions and other pandemic-induced challenges on project turnaround times. Analysing the timing of project starts providing 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.

Arguments from the Status Quo

Alsharif et al. highlighted that new construction projects in the United Kingdom (UK) were significantly affected by COVID-19 [33]. 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 endeavours. There is a significant negative impact of skilled labour reduction on construction project turnaround times during the COVID-19 pandemic in South Africa. This hypothesis argued that reductions in skilled labour due to COVID-19 are statistically associated with increased project completion times, thereby adversely affecting project schedules.

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

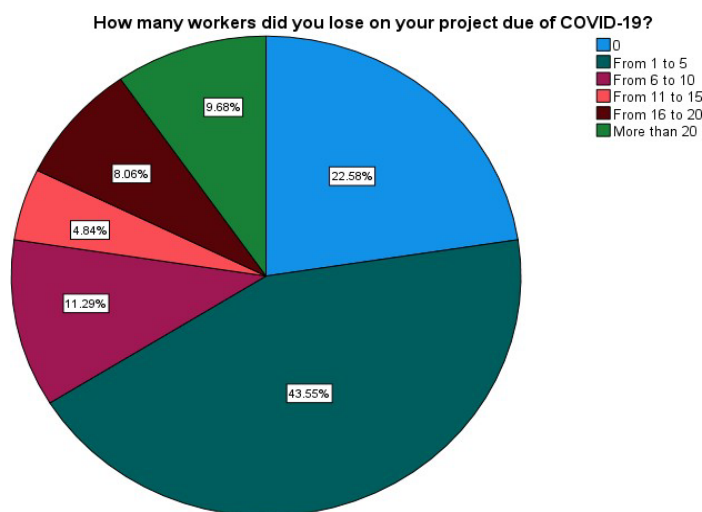


Figure 3: Workforce Loss on South African Construction Projects During COVID-19.

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

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.

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.

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.

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

These smaller segments represent projects with significant labour 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.

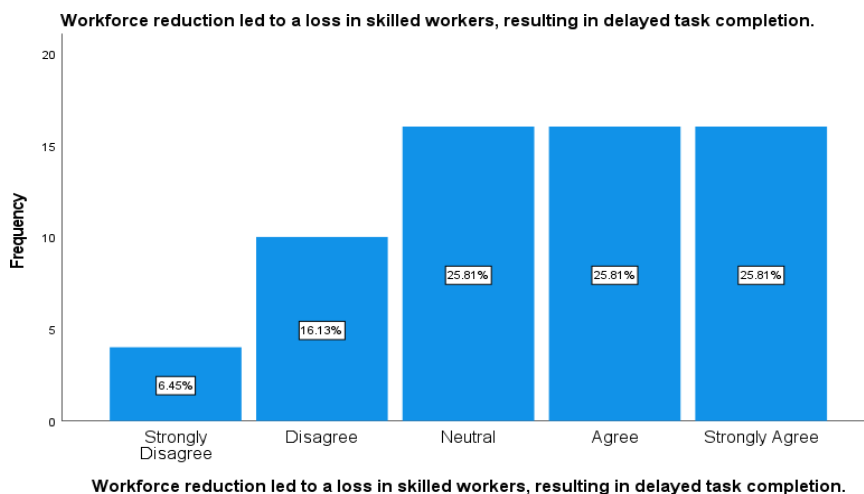


Figure 4: Skilled Worker Reduction and Delay Impact in Construction Projects.

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 categorised across a Likert scale ranging from "Strongly Disagree" to "Strongly Agree" [60,61].

Analysis

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 [62].

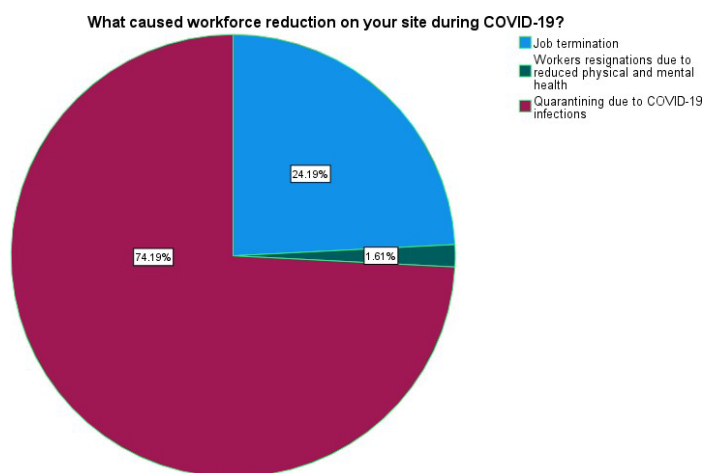


Figure 5: Causes of Workforce Reduction During COVID-19 in Construction.

The pie chart visualises 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 [63,64].

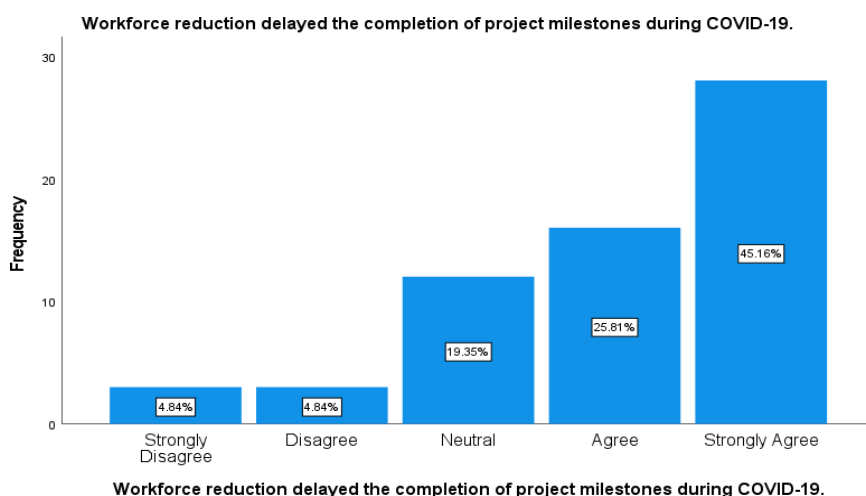


Figure 6: Workforce Reduction's Effect on Project Milestones During COVID-19.

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 categorised across a Likert scale ranging from "Strongly Disagree" to "Strongly Agree" [60,61].

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, where 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 labour availability, emphasising 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.

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 the majority of 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 labour. 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, the majority of 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 recognised workforce reduction as a significant factor delaying site activities, echoing findings from the literature, and underscoring the global challenges faced by contractors. Alsharif et al. noted that in the United States, the pervasive impact of COVID-19, particularly through worker infections, significantly hindered project timelines [33]. 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 [43].

Mixed Views on COVID-19 Interventions Improving Construction Schedules
 COVID-19 interventions resulted in improved project schedule.

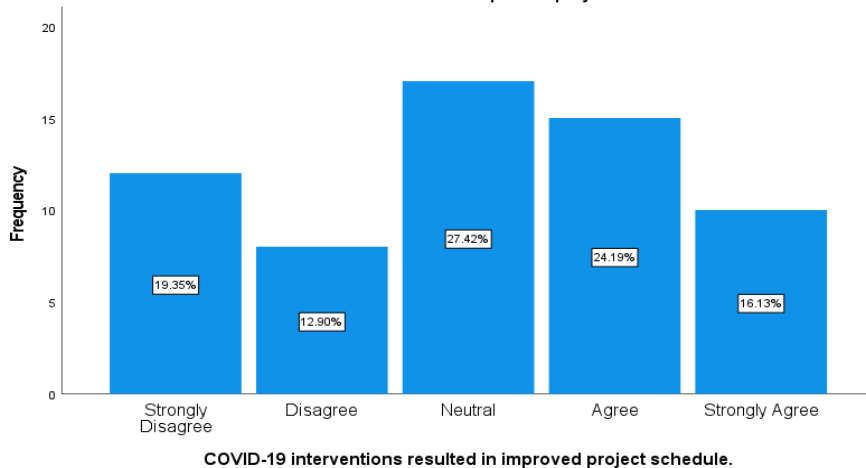


Figure 7: Impact of COVID-19 Interventions on Construction Project Schedules.

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 [33]. 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 stud'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.

Chronology of Construction Project Recovery Post-COVID Delays

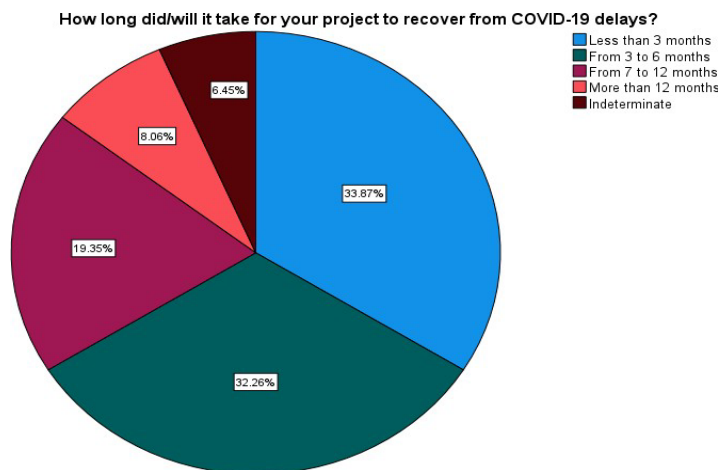


Figure 8: Project Recovery Time from COVID-19 Delays in Construction Industry.

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 normalisation. 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, including an 'other' option. This latter category received limited responses, with two indicating employment at Grade 1 contracting firms, and the remainder comprised of Implementing Agents, Consulting Engineers, or those unaffiliated with any specific CIDB grade. It is hypothesised 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 [54,65,66]. This study's outcomes indicated the highest participant representation in projects valued at R11 000 000 and above, signifying a 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 a 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. Conversely, 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 the majority of 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 labour availability on construction sites due to illness or social distancing measures aimed at controlling COVID-19 [59]. 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 [31]. A similar scenario was

reported in Singapore, where the isolation of foreign workers, a critical labour force in the construction sector, due to heightened infections in dormitories, led to project delays [67]. Job termination emerged as the secondary cause for workforce reduction, a predictable outcome [68]. 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 labour 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 Alsharif et al. found that many US study participants could not provide definite timelines due to the multifaceted influences of COVID-19 on project execution [33]. Olanrewaju et al. revealed that health and safety protocols could potentially reduce site productivity by half, suggesting similar project delays [69]. 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

The ACMTC theory posits that construction project management must adapt to the unpredictable nature of crises, such as pandemics, where minor disruptions can lead to significant impacts on project timelines due to non-linear dynamics and sensitivity to initial conditions [70,71]. The findings of this study, showing that even a minor overall workforce reduction had a disproportionate impact on project completion times, particularly due to the loss of skilled labour, which validates the ACMTC's tenet of non-linear responses to changes in system conditions. This aligns with the "butterfly effect" principle of chaos theory, where small initial differences may lead to vastly different outcomes [71]. Additionally, the research highlights the industry's adaptability and resilience, as recommended by the ACMTC. The adaptation involves strategic decision-making and operational flexibility, which are crucial for managing and mitigating the impacts of unforeseen disruptions [70]. This is evidenced by the construction industry's response to the pandemic through adjustments in workforce and safety measures, showcasing an emergent new order from chaos, a core aspect of chaos theory [71]. Therefore, the findings not only support the theoretical framework of ACMTC but also provides practical implications for construction project management during global disruptions. It emphasises the necessity for industries to embrace chaos as a catalyst for innovation and adaptation,

transforming challenges into opportunities for improving efficiency and resilience in project management [70-73].

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 [74]. 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 labour shortages on construction site operations. The literature also noted that adopting shift work and reduced working days led to further delays, attributable to a diminished on-site workforce. This literature review highlighted a gap in understanding the implications of such interventions on construction projects. 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.

Funding

This research received no external funding.

Acknowledgments

This research was completed as a Master of Science in Building degree at the University of the Witwatersrand, Johannesburg; with the Construction Education and Training Authority (CETA) being the bursary benefactor. On behalf of Nomsa Chabalala and myself, Malcolm Weaich, we extend our deepest gratitude to Dr. Prisca Simbanegavi for her invaluable guidance and unwavering support throughout our academic journey. We loved every second of our research journey with you! Dr. Simbanegavi's expertise and insightful feedback have been instrumental in shaping our research and enhancing our understanding. Her mentorship has not only enriched our learning experience but has also inspired us to pursue excellence in our scholarly endeavours. We are profoundly thankful for her dedication and the significant role she has played in our academic and professional development. A mentor like no other!

Conflict of Interest Statement

The authors declare no conflicts of interest.

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.

References

- [1] M. Weaich, P. Simbanegavi, P. Ndlovu, D. Root, T. Bedi, A. Parafiniuk, B. Latos, Y. Adewunmi, Achieving Sustainable Transdisciplinary Research in Construction Project Management: A Bibliometric Approach, (2024). <https://doi.org/10.31224/3550>.
- [2] K. Popper, *The Logic of Scientific Discovery*, Repr. 2008 (twice), Routledge, London, 2008.
- [3] 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/ghjdv>.
- [4] 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/gg5x2w>.
- [5] 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/gjhdxp>.
- [6] 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/ggt5h5>.
- [7] D. Huremović, Brief History of Pandemics (Pandemics Throughout History), *Psychiatry Pandemics Ment. Health Response Infect. Outbreak* (2019) 7–35. <https://doi.org/10/ghxsrr>.
- [8] 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/ggq7kd>.
- [9] 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/ghc6w4>.
- [10] R.Y. Elbay, A. Kurtulmuş, S. Arpacioğlu, E. Karadere, Depression, Anxiety, Stress Levels of Physicians and Associated Factors in COVID-19 Pandemics, *Psychiatry Res.* 290 (2020) 113130. <https://doi.org/10/gg8qtn>.
- [11] 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.
- [12] I. Ali, O.M. Alharbi, COVID-19: Disease, Management, Treatment, and Social Impact, *Sci. Total Environ.* 728 (2020) 138861. <https://doi.org/10/ggtx3m>.
- [13] 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/gk63j4>.
- [14] 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/gkbzj6>.

- [15] 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/gg7twr>.
- [16] R.Y. Elbay, A. Kurtulmuş, S. Arpacioğlu, E. Karadere, Depression, Anxiety, Stress Levels of Physicians and Associated Factors in Covid-19 Pandemics, *Psychiatry Res.* 290 (2020) 113130. <https://doi.org/10/gg8qtn>.
- [17] 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/gtrdzb>.
- [18] 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/gttz67>.
- [19] 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).
- [20] 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/gttz66>.
- [21] 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/gtrdxn>.
- [22] 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/ggv39m>.
- [23] 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/gtrc8g>.
- [24] 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/gttz69>.
- [25] 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/gpc39w>.
- [26] R.A. Waheeb, K.A. Wheib, B.S. Andersen, R. Al-Suhili, 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/gttz7g>.
- [27] 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/gtrc9h>.
- [28] 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/gtrc8g>.
- [29] 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/gtrdxn>.
- [30] I. Musonda, N. Rakolote, Impact of the COVID-19 Pandemic in the South African Construction Industry, *Acta Structilia* 29 (2022). <https://doi.org/10/gttz7k>.
- [31] 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).

- [32] 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).
- [33] 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/gm33zz>.
- [34] H. Singh, A. Singh, Principles of Complexity and Chaos Theory in Project Execution: A New Approach to Management, *Cost Eng.* 44 (2002) 23.
- [35] G. Williams, *Chaos Theory Tamed*, CRC Press, 1997.
- [36] R.-A. Thietart, B. Forgues, Chaos Theory and Organization, *Organ. Sci.* 6 (1995) 19-31. <https://doi.org/10/fgvmpt>.
- [37] 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/bwvfjh>.
- [38] 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/gkqx7z>.
- [39] T.A.N. Alenezi, Covid-19 Causes of Delays on Construction Projects in Kuwait, *Int. J. Eng. Res. Gen. Sci.* 8 (2020) 6-9.
- [40] 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/gh52q9>.
- [41] 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/gqf4q9>.
- [42] Y. Olum, *Modern Management Theories and Practices*, Uganda Makerere Univ. (2004) 1-24.
- [43] 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/gtrc7n>.
- [44] G.S. Goda, E.J. Soltas, *The Impacts of Covid-19 Illnesses on Workers*, National Bureau of Economic Research, 2022.
- [45] 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/gtrc9h>.
- [46] 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/gm324n>.
- [47] M.N.K. Saunders, P. Lewis, A. Thornhill, *Research Methods for Business Students*, Ninth edition, Pearson, Harlow, England ; New York, 2023.
- [48] C. Andrade, The Inconvenient Truth About Convenience and Purposive Samples, *Indian J. Psychol. Med.* 43 (2021) 86-88. <https://doi.org/10/fs24>.
- [49] W.E. Saris, *Design, Evaluation, and Analysis of Questionnaires for Survey Research*, Second Edition, Wiley, Hoboken, New Jersey, 2014.
- [50] 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/fxkk3>.
- [51] 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>.
- [52] 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/gqf4q4>.

- [53] A.P. Field, *Discovering Statistics Using IBM SPSS Statistics: and Sex and Drugs and Rock "N" Roll*, 4th edition, Sage, Los Angeles, 2013.
- [54] CIDB, Requirements for Grading | CIDB, (2021). <https://www.cidb.org.za/contractors/register-of-contractors/requirements-for-grading/> (accessed September 18, 2023).
- [55] 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/ghm7tr>.
- [56] A.P. Field, *Discovering Statistics Using IBM SPSS Statistics*, 5th edition, SAGE Publications, London, 2018.
- [57] J. Pallant, *Spss Survival Manual: A Step by Step Guide to Data Analysis Using IBM SPSS*, McGraw-hill education (UK), 2020.
- [58] J. Stevens, *Applied Multivariate Statistics for the Social Sciences*, Lawrence Erlbaum Associates Mahwah, NJ, 2002.
- [59] 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/gm4kqn>.
- [60] R. Likert, A Technique for the Measurement of Attitudes., *Arch. Psychol.* (1932).
- [61] 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/dgbz>.
- [62] L. Maseko, D. Root, V. Senthilkumar, Conceptual Framework for Collaborative Risk Management During the Design Phase of Green Building Projects Using Dsm, in: 2018: pp. 023-032.
- [63] 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>.
- [64] 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>.
- [65] CIDB, Register of Contractors Overview | CIDB, (2021). <https://www.cidb.org.za/contractors/register-of-contractors/overview/> (accessed April 3, 2024).
- [66] 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).
- [67] 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).
- [68] R. Jayathilaka, K. Waidyasekara, Contractual Implications Related to the Construction Industry in Pandemic Situations: A Review of Case Laws., (2022). <https://doi.org/10/gtrdmg>.
- [69] 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/gpc4t9>.
- [70] R.A. Thiétart, B. Forgues, Chaos Theory and Organization, *Organ. Sci.* 6 (1995) 19-31. <https://doi.org/10/fgvmpt>.

- [71] 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/bwvfjh>.
- [72] W. Wang, Z. Xia, Study of COVID-19 Epidemic Control Capability and Emergency Management Strategy Based on Optimized SEIR Model, *Mathematics* 11 (2023) 323. <https://doi.org/10/gttz6r>.
- [73] A. Hosny, M. Nik-Bakht, O. Moselhi, Physical Distancing Analytics for Construction Planning Using 4D BIM, *J. Comput. Civ. Eng.* 36 (2022) 04022012. <https://doi.org/10/gttz6q>.
- [74] 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.