# Journal of Construction Project Management and Innovation

ISSN 2223-7852

Volume 12 Number 1 December 2022

https://journals.uj.ac.za/index.php/JCP

# ABOUT JCPMI

**The Journal of Construction Project Management and Innovation** is published bi-annually (twice per year) through the Sustainable Human Settlement and Construction Research Centre (SHSCRC) of the University of Johannesburg by the University of Johannesburg.

**The Journal of Construction Project Management and Innovation** is an open access journal that publishes all sorts of research on Construction project management; Project management; Design and construction management processes; Housing and infrastructure development; Stakeholder management; Project planning and project impact assessments; Design and implementation of labour-intensive projects; Procurement management; Management of construction companies; Industry development; Knowledge management in construction; Empowerment of women; Innovation; Project financing; Current and emerging infrastructure issues in developing countries as well as other issues. The goal of JCPMI is to broaden the knowledge of construction professionals and academicians by promoting free access and providing valuable insight to construction-related information, research and ideas. JCPMI is a bi-annual publication and all articles are peer-reviewed.

# Submission of Manuscripts

Manuscript submission can be done using the link
https://journals.uj.ac.za/index.php/JCPMI/login

For all other correspondence that cannot be sent by email, please contact the editorial office (JCPMI2010@gmail.com, caigbavboa@uj.ac.za, thwaladw@unisa.ac.za).

The Journal of Construction Project Management and Innovation will only accept manuscripts submitted online. Please read the Instructions for Authors before submitting your manuscript.

## Editors-in-Chief



## Deputy Editors

# Editorial Board

# Editorial Policy and Submission Guidelines

## Overview

As part of the process of ensuring quality, the Journal of Construction Project Management and Innovation (JCMPI) Editors subscribe to the open-access publishing code of the Academy of Science of South Africa (ASSAf).

Only papers with a clear focus on construction project management and innovations with relevance to the built environment are and will be published in the journal.

The JCPMI is an open-access journal that publishes research scholarly work on construction project management; project management; design and construction management processes; housing and infrastructure development; stakeholder management; project planning and project impact assessments; design and implementation of labour-intensive projects; procurement management; management of construction companies; industry development; knowledge management in construction; empowerment of women; innovation; project financing; current and emerging infrastructure issues in developing countries as well as other issues. The goal of the JCPMI is to broaden the knowledge of construction professionals and academicians by promoting free access and providing valuable insight to construction-related information, research and ideas.

The journal strives to ensure diversity in its publication by ensuring papers from different countries are represented in each issue and volume published.

Authors are encouraged to submit scholarly articles, review articles, practical library work, short communications, book reviews or letters to the editor.

Items that have been published elsewhere should be submitted only with permission of the original publisher, and this should be clearly indicated and the improvement to such publication annotated for ease of reference.

## Editing Procedure (Peer Review Policy)

All submitted manuscripts are reviewed by an editor and members of the Editorial Board or at least two qualified outside reviewers. Authors cannot nominate reviewers. Only reviewers selected from the journal's database with specialization in the subject area will be contacted to evaluate the manuscripts.

The review process will be double-blind review.

The feedback from reviewers is checked and reviewed by the journal editor assigned to the manuscript to ensure quality and relevance of the review comments, while all final review communications are sent to the authors by the Editor-in-Chief.

In submitting a revised manuscript, authors are mandated to submit a report detailing how they have responded to the reviewers' comments. The journal editor checks to ensure that all recommended changes for improvement of the article have been substantively attended to before initiating a follow-up blind reviewer process. After the peer reviewers have read and evaluated the manuscript, one of the following three recommendations for publication is made:

- Accept the manuscript for publication with minor revisions.
- Accept the manuscript for publication with major revisions.
- Reject the manuscript for publication.

After the editor receives the peer reviewers' recommendations, they are forwarded to the author, who will then perform the necessary revisions and submit a new draft within a time frame determined by the editor. The editor then reviews the final draft to determine whether the manuscript is ready for publication, or if it requires further peer review. Once a manuscript is ready for publication, it is forwarded to the copy editor who will review the manuscript to correct spelling, punctuation, and grammatical errors, and to ensure that the text adheres to JCPMI's formatting and style guidelines. Once the copy editor's work is done, the managing editor performs a final review of the manuscript and publishes it.

It is the goal of the JCPMI to publish manuscripts within the shortest possible time after submission.

By submitting a manuscript to JCPMI, authors agree that journal editors have the right to check their manuscript via iThenticate. However, it is the responsibility of authors to check their papers for any plagiarism issue before submitting to the journal. But all submitted papers are by default checked for plagiarism using iThenticate on the OJS platform. Should the editors detect potential plagiarism issues, the paper will be temporarily suspended and send back to the authors.

## Conflict of Interest Statement

The Editors-in-Chief are allowed to publish papers occasionally in the journal. Such publication must be relevant to the built environment, and the full review process should be followed and managed by one of the deputy editors. Similarly, the Deputy Editors are allowed to publish papers occasionally in the journal. Such publication must be relevant to the built environment and the full review process should be followed and managed by one of the Editors-in-Chief.

## Copyright Policy

Authors who publish in the *Journal of Construction Project Management and Innovation* agree to the following terms:

Authors retain copyright and grant the journal right of first publication with the work and allows others to share the work with an acknowledgement of the work's authorship and initial publication in this journal.

Submission of a manuscript to JCPMI implies that the work described has not been published before (except in the form of an abstract or as part of a published lecture, or thesis); that it is not under consideration for publication elsewhere; that if and when the manuscript is accepted for publication, the author(s) still hold the copyright and retain publishing rights without restrictions. Authors or others are allowed to multiply the article as long as it is not for commercial purposes. Any use and or copies of this journal in whole or in part must include the customary bibliographic citation, including author attribution, date and article title.

## Errata

All articles published in JCPMI are subject to an editorial review process. On acceptance, electronic proofs will be sent (email attachment) to the corresponding author as a PDF file. Page proofs are considered to be the final version of the manuscript. With the exception of typographical or minor clerical errors, no changes will be made in the manuscript at the proof stage. After publication, authors who notice any error must contact the Journal Manager who will determine the impact of the change and decide the necessary line of action to be taken.

## Submission Guidelines

**See guidelines:**

**https://journals.uj.ac.za/index.php/JCPMI/about/submissions**

## Institutional Affiliation

JCPMI is an institutional journal, and editors are accountable to the University of Johannesburg.

JCPMI is published bi-annually (twice per year) through the Sustainable Human Settlement and Construction Research Centre (SHSCRC) of the University of Johannesburg by the University of Johannesburg

JCPMI is an open-access journal, and pdf versions of all papers are available on the journal website https://journals.uj.ac.za/index.php/JCPMI/login

JCPMI is accredited by the South African Department of Higher Education and Training, and the journal editors will continue to seek and maintain the quality standards necessary for ongoing accreditation.

# Instructions for Authors

**Electronic submission** of manuscripts is strongly encouraged, provided that the text, tables, and figures are included in a single Microsoft Word file (preferably in Arial font).

The **cover letter** should include the corresponding author's full address and telephone/fax numbers and should be in an email message sent to the Editor, with the file, the name of which should begin with the first author's surname, as an attachment.

**Article Types**

Three types of manuscripts may be submitted:

**Regular Articles**

All portions of the manuscript must be typed 1.5 spacing, and all pages numbered starting from the title page. The font size must be 12.

**Regular Articles**

These should describe new and carefully confirmed findings, and experimental procedures should be given in sufficient detail for others to verify the work. The length of a full paper should be the minimum required to describe and interpret the work clearly. The length of a full paper should be between 4000 – 7000 words.

Review Process

**Short Communications**

A short communication is suitable for recording the results of complete small investigations or giving details of new models or hypotheses, innovative methods, techniques or apparatus. The style of main sections need not conform to that of full-length papers. Short communications are 2 to 4 printed pages (about 6 to 12 manuscript pages) in length.

**Reviews**

Submissions of reviews and perspectives covering topics of current interest are welcome and encouraged. Reviews should be concise and no longer than 4-6 printed pages (about 12 to 18 manuscript pages). Reviews are also peer-reviewed.

**Review Process**

All manuscripts are reviewed by an editor and members of the Editorial Board or qualified outside reviewers. Authors cannot nominate reviewers. Only reviewers randomly selected from our database with specialization in the subject area will be contacted to evaluate the manuscripts. The process will be blind review. Decisions will be made as rapidly as possible, and the journal strives to return reviewers' comments to authors as quickly as possible. The editorial board will re-review manuscripts that are accepted pending revision. It is the goal of the JCPMI to publish manuscripts within the shortest possible time after submission.

**Regular Articles**

All portions of the manuscript must be typed in double spacing and all pages numbered, starting from the title page.

**The Title** should be a brief phrase describing the contents of the paper. The Title Page should include the authors' full names and affiliations, the name of the corresponding author along with phone, fax and email information. Present addresses of authors should appear as a footnote.

The **Abstract** should be informative and completely self-explanatory, briefly presenting the topic, stating the scope of the experiments, indicating significant data, and pointing out major findings and conclusions. The Abstract should be 100 to 300 words in length. Complete sentences, active verbs, and the third person should be used, and the abstract should be written in the past tense. Standard nomenclature should be used and abbreviations should be avoided. No literature should be cited. Following the abstract, about 3 to 10 key words that will provide indexing references should be listed.

A list of non-standard **Abbreviations** should be added.

In general, non-standard abbreviations should be used only when the full term is very long and used often. Each abbreviation should be spelled out and introduced in parentheses the first time it is used in the text.

**The Introduction** should provide a clear statement of the problem, the relevant literature on the subject, and the proposed approach or solution. It should be understandable to colleagues from a broad range of scientific disciplines.

**Materials and methods** should be complete enough to allow experiments to be reproduced. However, only truly new procedures should be described in detail; previously published procedures should be cited, and important modifications of published procedures should be mentioned briefly. Capitalize trade names and include the manufacturer's name and address. Subheadings should be used. Methods in general use need not be described in detail.

**Results** should be presented with clarity and precision. The results should be written in the past tense when describing findings in the authors' experiments. Previously published findings should be written in the present tense. Results should be explained, but largely without referring to the literature. Discussion, speculation and detailed interpretation of data should not be included in the Results but should be put into the Discussion section.

**The Discussion** should interpret the findings in view of the results obtained in this and in past studies on this topic. State the conclusions in a few sentences at the end of the paper. The Results and Discussion sections can include sub-headings, and when appropriate, both sections can be combined.

**The Acknowledgments** of people, grants, funds, etc. should be brief.

**Tables** should be kept to a minimum and be designed to be as simple as possible. Tables are to be typed in double-spacing throughout, including headings and footnotes. Each table should be on a separate page, numbered consecutively in Arabic numerals and supplied with a heading and a legend. Tables should be self-explanatory without reference to the text. The details of the methods used in the experiments should preferably be described in the legend instead of in the text. The same data should not be presented in both table and graph form or repeated in the text.

**Figure legends** should be typed in numerical order on a separate sheet. Graphics should be prepared using applications capable of generating high resolution GIF, TIFF, JPEG or PowerPoint before pasting in the Microsoft Word manuscript file. Tables should be prepared in Microsoft Word. Use Arabic numerals to designate figures and upper-case letters for their parts (Figure 1). Begin each legend with a title and include sufficient description so that the figure is understandable without reading the text of the manuscript. Information given in legends should not be repeated in the text.

**References**: In the text, a reference identified by means of an author's name should be followed by the date of the reference in parentheses. When there are more than two authors, only the first author's name should be mentioned, followed by 'et al '. In the event that an author cited has had two or more works published during the same year, the reference, both in the text and in the reference list, should be identified by a lower case letter like 'a' and 'b' after the date to distinguish the works.

Examples:

Aigbavboa (2012), Aigbavboa et al. (2012), (Thwala, 2000), (Aigbavboa and Thwala, 2012), (Aigbavboa, 2008; Lesito, 2007a, b; Aigbavboa, 2010, 2011), (Thwala et al., 2001)

**References** should be listed at the end of the paper in alphabetical order. Articles in preparation or articles submitted for publication, unpublished observations, and personal communications should not be included in the reference list but should only be mentioned in the article text (e.g., A. Kingori, University of Nairobi, Kenya, personal communication). Journal names are abbreviated according to Chemical Abstracts. Authors are fully responsible for the accuracy of the references.

Examples:

Aigbavboa CO (2010). Residential satisfaction in low-income housing: a South Africa perspective. Journal of Construction Project Management and Innovation. 1(2): 14 – 20.

Aigbavboa CO, Lesito K (2012). ICT benefit in South Africa Construction Journal of Construction Project Management and Innovation. 2(2): 75 – 81.

**Short Communications**

Short Communications are limited to a maximum of two figures and one table. They should present a complete study that is more limited in scope than is found in full-length papers. The items of manuscript preparation listed above apply to Short Communications with the following differences: (1) Abstracts are limited to 300 words; (2) instead of a separate Materials and Methods section, experimental procedures may be incorporated into Figure Legends and Table footnotes; (3) Results and Discussion should be combined into a single section.

**Proofs and Reprints**: Electronic proofs will be sent (email attachment) to the corresponding author as a PDF file. Page proofs are considered to be the final version of the manuscript. With the exception of typographical or minor clerical errors, no changes will be made in the manuscript at the proof stage.

## Fees and Charges

**No fee is paid for the publication of article(s) in JCPMI. Authors' submissions are only required to meet the peer review process.**



Submission of a manuscript implies: that the work described has not been published before (except in the form of an abstract or as part of a published lecture, or thesis); that it is not under consideration for publication elsewhere; that if and when the manuscript is accepted for publication, the authors agree to automatic transfer of the copyright to the publisher.

## Disclaimer of Warranties

In no event shall the management of the Journal of Construction Project Management and Innovation be liable for any special, incidental, indirect, or consequential damages of any kind arising out of or in connection with the use of the articles or other material derived from the JCPMI, whether or not advised of the possibility of damage, and on any theory of liability.

This publication is provided "as is" without warranty of any kind, either expressed or implied, including, but not limited to, the implied warranties of merchantability, fitness for a particular purpose, or non-infringement. Descriptions of, or references to, products or publications does not imply endorsement of that product or publication. While every effort is made by JCPMI management to see that no inaccurate or misleading data, opinion or statements appear in this publication, they wish to make it clear that the data and opinions appearing in the articles and advertisements herein are the responsibility of the contributor or advertiser concerned. JCPMI management makes no warranty of any kind, either express or implied, regarding the quality, accuracy, availability, or validity of the data or information in this publication or of any other publication to which it may be linked.

# Table of Contents

## Volume 12 Number 1 December 2022

### ARTICLES

Journal of Construction Project Management and Innovation, 12(1): 1-16, 2022
ISSN 2223-7852


# Evaluating modelling methods for mobile crane lifting operations in South Africa

**De Wet van Niekerk[1] and Michiel C. Bekker*[2]**

[1&2]Department of Engineering and Technology Management,
University of Pretoria, South Africa

*Email: giel.bekker@up.ac.za

**ABSTRACT**
The successful completion of construction projects is dependent on safe and efficient crane operations. As modularized (off-site) construction is increasingly replacing traditional on-site activities, the evaluation of mobile crane lifting modelling should be evaluated. This paper investigates current modelling practices adopted and utilised by South African firms for the planning and/or designing of mobile crane lifting operations, the influencing factors affecting the choice of modelling methods by firms, and the impact they have on project performance. Quantitative data gathered revealed that firms who are actively adopting virtual modelling as a planning tool for mobile crane lifting operations, have higher success rates with regards to achieving targeted project performance measures such as scheduling-, safety-, and achieving customer satisfaction goals. The research revealed that the two most significant factors influencing the choice of firms to adopt virtual modelling as a planning tool, was found to be Awareness and Perceived usefulness. Findings from the research suggest that failure to adopt innovation in this field could have long term negative consequences to the market share of firms operating within this industry. It is therefore suggested that South African firms within the lifting industry improve their competitiveness by ensuring they invest in the adoption of virtual modelling as a planning tool for mobile crane lifting operations.

**Keywords:** Virtual modelling, Lift planning, Crane optimization, Construction project performance, 2D modelling, Mathematical modelling.

## 1. INTRODUCTION

During the planning of lifting operations, lift planners needs to consider dynamic, iterative processes to enable the optimization of operations that are safe, efficient, and effective (Lei et al., 2016). Initial investigations found that the majority of current lift planning practices still involves the use of outdated static 2-Dimensional (2D) modelling techniques for the design and evaluation lifting operation feasibility. These outdated and static approaches cause inferior crane operations leading to crane relocations and/or collision errors which can be costly and time-consuming (Chi et al., 2010). Furthermore, applying static 2D modelling techniques for dynamic activities such as lifting activities, are some of the root causes of misunderstandings and/or miscommunication errors among project team members (Han et al., 2015).

Several studies have been conducted on the topic of crane lift planning with the purpose of overcoming the limitations of traditional static modelling. Researchers such as Han et al.,(2015) proposed the use of 3D visualization software to aid designers in developing collision-free lift plans. By reconstructing a construction site and using 3D simulation software to simulate crane operations, virtual modelling methods are able to assist project teams to identify collision risks, optimize operational efficiency, enhance decision making, and improve communication among team members.

At the time of this study, no local standard industry practice for the planning of lifting operations in South Africa could be identified. Therefore, the primary objective of this study to investigate current practices for planning/modelling of mobile crane lifting operations in South Africa.

By identifying current practices for modelling in South Africa, insight can be gained into what modelling practices have been adopted and the reason for adoption. The study also aimed to identify the linkage between influential factors affecting technology adoption in the construction industry and the choice of modelling method. By understanding what is being adopted as well as why it is being adopted, the research aims to provide insight into the needs and concerns of firms in the local lifting industry regarding the adoption of modern modelling practices for lift planning.

The research also investigated the relationship between modelling practices and key project performance indicators. The results highlight best practices for planning of mobile crane lifting operations in South Africa.

These objectives were achieved by answering the following research questions:

- What modelling methods, relating to designing and/or planning of mobile crane lifting operations, are currently being applied in South Africa?
- Which factors correlate with the choice of modelling method utilized by firms for planning and/or designing of mobile crane lifting operations in South Africa?
- How does the choice of modelling method affect project performance within the context of mobile crane lifting operations in South Africa

## 2. LITERATURE REVIEW

### 2.1 Lift planning

In construction projects, planning of crane-related lifting operations has an impact on project success (Zhang and Pan, 2020). To be able to successfully execute a mobile crane lifting operation, an optimal lift plan needs to be developed by competent lift planners having the required skills, knowledge and experience to be able to solve a complex combinatorial optimization problem (García de Soto et al., 2020).

Traditionally, lift planning involved operations using 2D drawings or, in more complex lifts, static 3D drawings. Using these techniques, lift planners focused primarily on evaluating crane lifting operations only at the pick and set points of the load to be lifted, rather than evaluating the entire lifting operation. This approach often resulted in costly errors in crane lifting operations such as collision errors, miscommunications and/or crane relocations (Zhang and Pan, 2019).

Significant research and development have been done in recent years to help address these problems. Some notable research include, decision-making based on multiple criteria in crane selection (Jalali et al., 2018), visualizations for lifting collision analysis (Chi and Kang, 2010), heuristic searching for lift path planning (Wu et al., 2018), and AI-based algorithms for location optimization (Lien and Cheng, 2014).

### 2.2 Lift planning optimization

Crane-related lifting operations can be regarded as a system containing different entities that interact with each other in order to complete a lifting task. Various methods exist that can be used to experiment with this system. Figure 1(Law et al., 2000) shows a diagram of the different methods that can be used to study a crane lifting operation. It is generally not economically feasible to experiment with the on-site actual crane operations as a system. A better alternative is to construct a representative model of the crane lifting operation. This model can be either physical, mathematical, or virtual (see Figure 2).

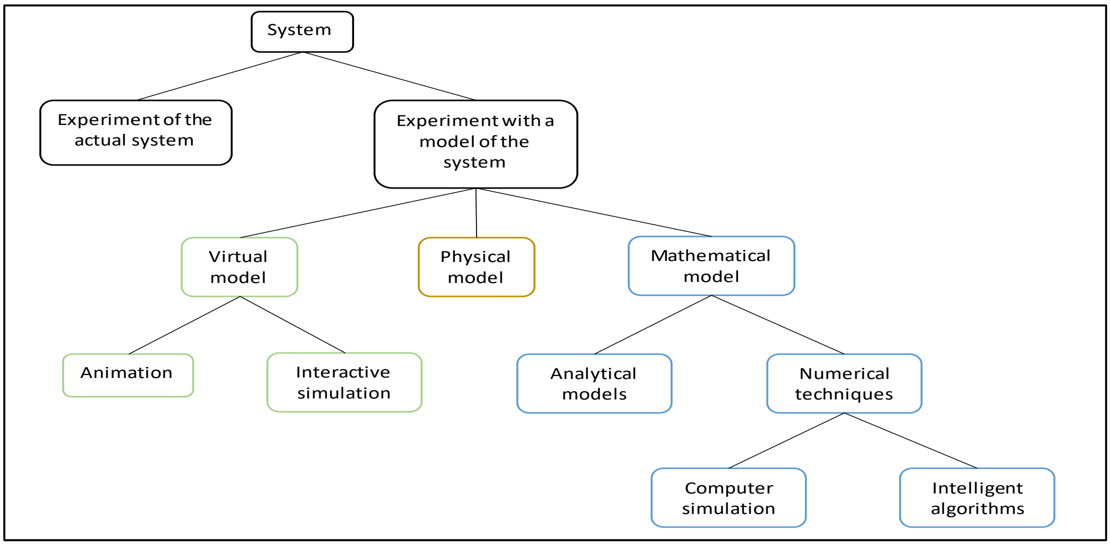


**Figure 1:** Methods of experimenting with crane lifting operations (Law et al., 2000)

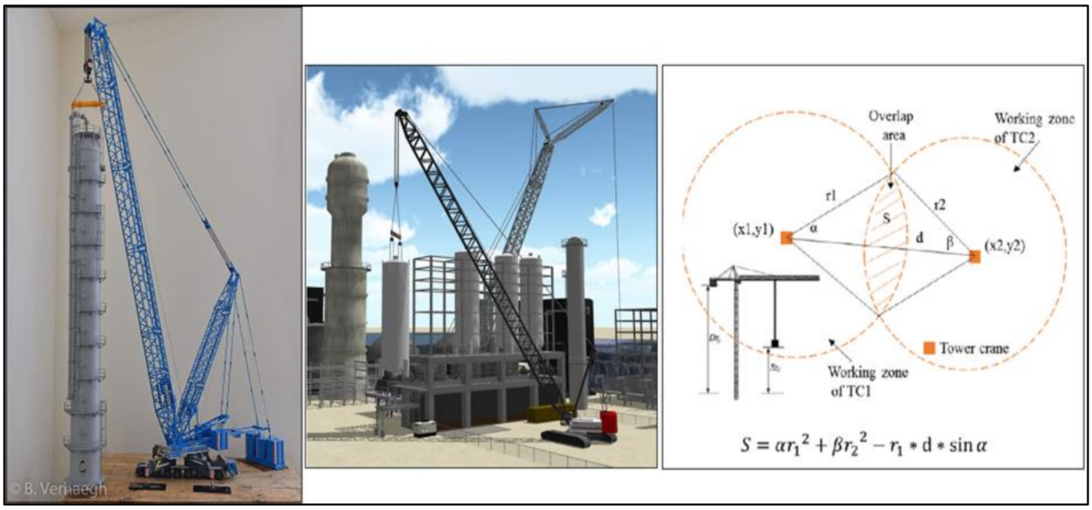


**Figure 2:** Types of models for a crane lift-system. Physical (left), virtual (middle), and mathematical (right)

### 2.2.1 *Experimenting using mathematical modelling*

In a mathematical model, a defined set of constraints can be created in which input variables can be minimized or maximized with respect to a clear objective function (Marzouk and Abubakr, 2016). Mathematical models are commonly examined using analytical and/or numerical techniques such as intelligent algorithms or computer simulations. Analytical methods are recommended when the mathematical model is not complex as these methods provide an exact solution for the model. Complex models are examined using numerical techniques which provide approximate solutions and involves a trial-and-error approach to obtain the approximate solution. Lifting operations are often modelled using numerical approaches since optimum lift planning of lifting operations involve complex planning and decision-making processes.

Numerical methods (using computer simulations) make it possible to reproduce a system's behavior by simulating the outcomes of a mathematical model using computer software. This simulation can then be used evaluate the performance of complex systems (Cantot and Luzeaux, 2013). As computer technology is advancing, the use of simulations in construction planning is increasingly aiding in developing better project plans, improving material handling systems, optimizing decision making process, and improving project productivity in terms of project costs and durations (Song and AbouRizk, 2006). Simulation methods in lifting operations have also been explored in recent years such as discrete-event simulation as a modeling method for movement of mobile cranes (ElNimr, Fagiar et al. 2016) and layout planning for tower cranes using an agent-based simulation (Younes and Marzouk, 2018).

Intelligent algorithms (as a numerical solution to mathematical modelling) have gained traction in recent years as faster heuristics and big data analyzing capabilities have made intelligent algorithms superior to numerical simulation methods in many ways. In recent decades, Intelligent algorithm methods, such as artificial intelligence (AI), have been introduced into the construction industry with the aim of making machines perform in a smart way by solving complex decision-making/optimization problems (Negnevitsky, 2005). Intelligent algorithms are capable of numerically solving complex mathematical problems by mimicking human intelligence and/or behaviors, such as decision-making learning and perception.

Artificial neural networks (ANN's) are one of the most popular approaches to machine learning and have become a common intelligent algorithm modeling technique in the field of lifting operations. Applications of ANN's and other AI-based models for lifting operations have yielded significant results in improved accuracy, productivity, and reliability of lift planning. Furthermore, AI-based numerical models have made it possible to simultaneously evaluate multiple planning components (Hornaday, Haas et al., 1993).

#### *2.2.2 Experimenting using virtual modelling*

A 3D virtual model can be described as a digital reconstruction/representation of a physical object, which can be built using relevant computer software. Animations using Building Information Management (BIM) software combined with Augmented Reality (AR) or Virtual Reality (VR) using interactive simulations, are the most commonly used methods for virtually experimenting with crane lifting operations (Bouchlaghem et al., 2005).

The construction industry has adapted well to the use of BIM software in correlation with computer animation software for generating construction sequencing animations. The combined use of these technologies has been successful in enhancing communication between various project stakeholders (Zhang and Pan, 2020). Han et al (Han et al., 2015) noted the following benefits of utilizing animating software for lifting operations:

- Increased productivity – Potential spatial conflicts are easily identified and eliminated.
- Improved communication, understanding and collaboration between project stakeholders prior to lifting operations.
- Improved confidence and morale of the project lifting team - By providing a visual pre-lecture of the lifting operation, team members gain a better understanding of the lifting task to be executed.

3D virtual modeling identifies the working radii and clearances during crane operations concurrently in order to validate and confirm the feasibility of each possible scenario, including crane locations, selected crane types, and crane lifting path. If spatial errors are identified in the 3D model, the selected crane model, crane location, or crane lift path is deemed to be unacceptable, and the relevant analysis is restarted.

The lack of descriptiveness and information in 2D drawings can lead to misunderstanding and miscommunication among project participants, resulting in poor decision making and the delivery of lower quality projects to clients (Han et al., 2015). Project participants may select an inefficient scenario because of the lack of information, such as uncertain clearances during crane operation when more than one feasible scenario exists. These uncertainties can lead to a faulty decision, which in turn increases operation time and cost for transportation and installation of the crane while necessitating an additional support system, even though a more efficient scenario utilizing an economical crane model with less operation time is available.

3D virtual modeling provides sequences of all lifts, complete with all the required information to facilitate better and faster communication, understanding and collaboration among participants so that effective and efficient decision making can be implemented resulting in productivity improvement. Furthermore, 3D virtual modeling assist project teams to identify potential high-risk areas and to design efficient and effective crane operations, so that productivity can be increased by reducing site errors, cost, and time (Han et al., 2015).

### 2.3 Technology Adoption in Construction

Research done by Akbarnezhad et al. (2016) proposed that, based on the benefits and risks of Building Information Modelling (BIM) adoption, and theories of implementing innovations in the construction industry, influential factors for innovation adoption can be categorised into the following three groups: adoption motivation, organizational competency, and ease of implementation.

Adoption motivation relates to the initial stages of implementing innovative processes and involves developing an awareness of the innovation as well as perceiving the need for utilizing/adopting the innovation (Sebastian et al., 2009). Existing literature on technology adoption in the field information technology have categorised perceived usefulness of BIM implementation, organizational innovativeness, subjective norms, and awareness as major motivations for BIM adoption (Lee et al., 2013).

According to Akbarnezhad et al. (2016), organizational competency can be measured in the following areas: organizational support, expertise, and organizational intention. Technical issues with software technology have been highlighted by previous studies as the main barrier for information technology adoption in the construction industry (Gledson et al., 2012). The primary factors contributing to ease of implementation are (Akbarnezhad, 2016): Ease of operation, ease of maintenance and, down time.

### 2.4 Research review

The process of lift planning optimization can be facilitated by a reconstructed model of the actual lifting operation. Different modelling methods include physical modelling, mathematical modelling, and virtual/3D modelling. Virtual modelling (through the integration of BIM and computer animation software) has been recognized as an effective method for crane location optimization and lift path planning. The literature review identified influential factors affecting technology adoption in the construction industry. These factors were used as independent variables in the integrated framework developed for this research in order the evaluate current modelling practices for mobile crane operations in South Africa.

## 3. CONCEPTUAL METHOD

The aim of this research was to identify the factors and their impact on the choice of modelling methods for planning of mobile crane lifting operations, and secondly, to develop and investigate the linkage between the choice of modelling method and project performance. The integrated framework developed for this research is shown in Figure 2.

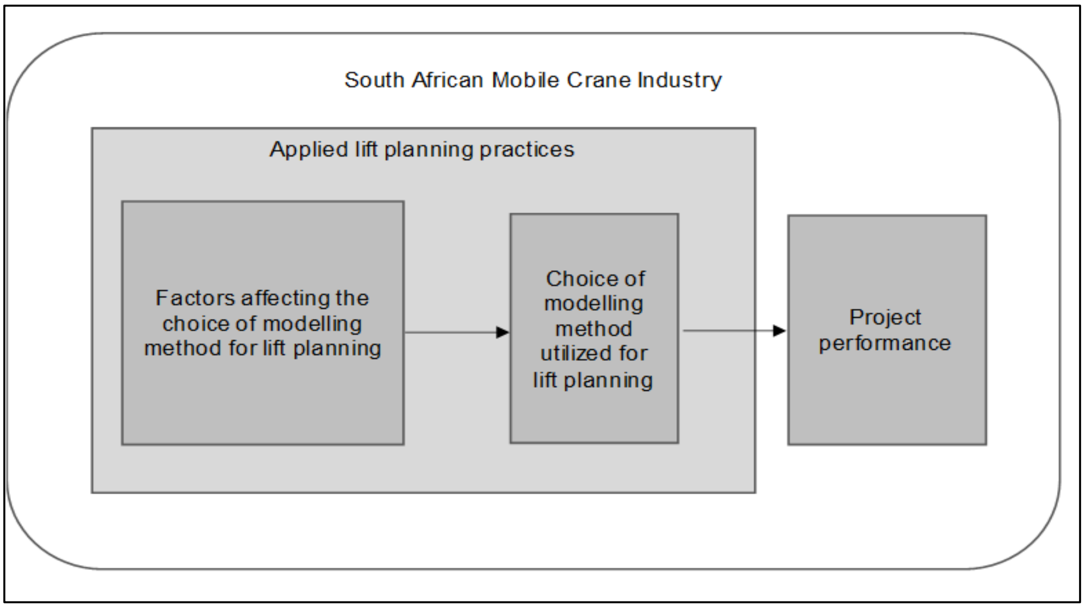


**Figure 2:** Integrated framework for investigating lift planning practices in South Africa for modelling of mobile crane lifting operations

In developing the integrated framework shown in Figure 2, a hypothesis of each influencing factor's relationship with the choice of modelling method was formulated as follows:

**H1-1**: Perceived usefulness has a positive effect on the choice of adopting advanced modelling methods (i.e., virtual modelling and mathematical modelling).

**H1-2**: The more innovative a firm, the more advanced the applied modelling method will be.

**H1-3**: Client preferences will influence the type of modelling method that a firm uses.

**H1-4**: The more knowledgeable a firm is regarding the applications and benefits of a specific technology type, the more likely they are to utilize that technology.

**H1-5**: A firm that executes larger, more complex lifting projects will most likely utilize more advanced modelling methods.

Hypotheses of the impact that virtual modelling has on project performance was formulated as follows:

**H2-1**: Utilization of virtual modelling methods for planning of lifting operations increase the percentage of projects that meet their schedule goals.

**H2-2**: Utilization of virtual modelling methods for planning of lifting operations increase the percentage of projects that meet their safety goals.

**H2-3**: Utilization of virtual modelling methods for planning of lifting operations increase the percentage of projects that meet their customers' requirements.

The analytical framework for the study is shown in Figure 3 below and was composed from the integrated framework shown in Figure 2.

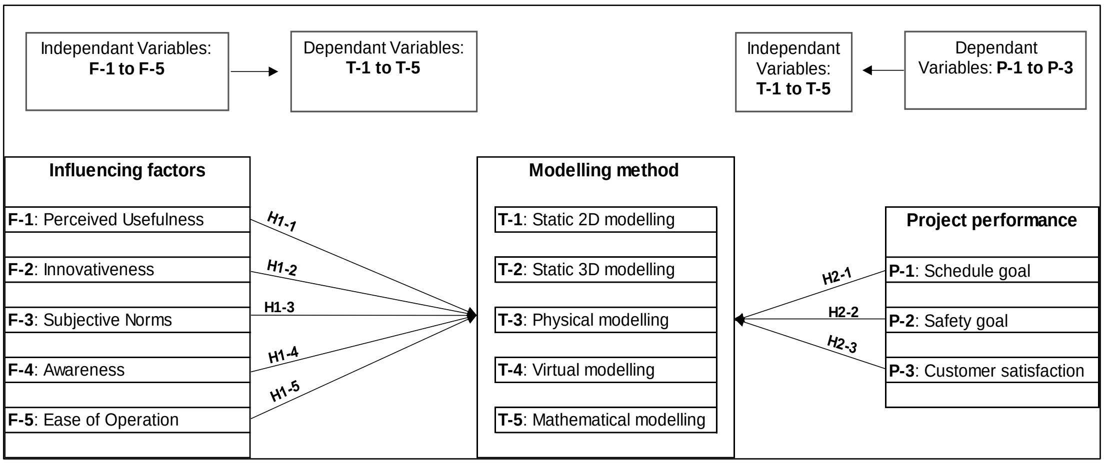


**Figure 3:** Analytical framework for hypotheses testing.

## 4. RESEARCH DESIGN AND METHODOLOGY

A quantitative research approach was used to employ a self-administered online questionnaire survey to investigate the linkage between influencing factors affecting the choice of modelling method utilized by lift planners in South Africa, and the impact the preferred modelling method has on project performance.

The survey questions were composed from the integrated framework shown in Figure 2. The unit of analysis for the study was the mobile crane industry of South Africa with the technical design and planning staff of the firms within this industry, comprising the unit of analysis. The questionnaire was organized into the following four sections:

*General information*: This section was used to establish the individual profiles of the respondents in terms of current role in the company, experience and technical skills, qualifications.

*Choice of modelling method*: This section was used to indicate what type of lift planning support tools are used by the respondent and was measured as a percentage of projects in the past 5 years.

*Factors affecting the choice of modelling method*: This section was used to identify the factors affecting the choice modelling method.

*Project Performance*: This section relates to the impact the type of lift planning tool/technique/software has on project performance.

The sample population consisted of individuals who are actively working at firms with a core business relating to lifting equipment and/or the transportation/installation of heavy machinery. The Lifting Equipment Engineering Association of South Africa (LEEASA) lists approximately 110 mobile crane-related firms in South Africa who are registered at LEEASA. However, not all service providers registered with LEEASA are involved with actual mobile crane lifting operations, as the LEEASA covers a diverse set of load handling service providers. A conservative assumption was therefore made to use a sample size greater than a 100 to accurately represent the mobile crane lifting industry of South Africa.

Choice of modelling method was measured by asking the respondents if they have used any of the modelling methods in Table 1 by indicating the percentage of projects over the last 5 years which have used that specific modelling method for design and/or analysis of mobile crane lifting operations.

**Table 1:** Modelling methods for lift planning

| Modelling method for lift planning | |
|---|---|
| T-1 | Static 2D modelling (drawings and/or sketches) |
| T-2 | Static 3D modelling (drawings and/or sketches) |
| T-3 | Physical modelling (solid 3D model) |
| T-4 | Virtual modelling (animations and/or interactive simulation) |
| T-5 | Mathematical modelling (analytical techniques and/or numerical techniques) |

The factors affecting the choice of modelling method are ordinal discrete variables. A summary of the quantitative input factors and their definitions used for this research is shown in Table 2. The measuring method comprised of a five-point Likert-type scale ranging from "strongly disagree" (score 1) to "strongly agree" (score 5).

**Table 2:** Factors affecting the choice of modelling method

| Factors | | Definition |
|---|---|---|
| F-1 | *Perceived Usefulness* | The degree to which person believes that utilizing a system would enhance the performance of his or her portfolio of work tasks. |
| F-2 | *Innovativeness* | A measure of the processes in place for organizations to introduce new ideas, workflows, methodologies, services, and/or products. |
| F-3 | *Subjective Norms* | An individual's perception that most people, who are important to him/her, think that he/she should or should not perform the behaviour. |
| F-4 | *Awareness* | The degree to which an organization is familiar and knowledgeable on the existence, applications, and capabilities of the innovative technology. |
| F-5 | *Ease of operation* | The degree to which the technology can assist a user in his/her portfolio of work tasks. |

The key project performance indicators that were measured by this study were schedule targets, safety goals, and customer satisfaction. These performance indicators were measured as ordinal discrete variables, indicating the percentage of projects executed in the past 5 years that met the relevant performance targets for each of these indicators. The respondents were asked to indicate their answer by selecting a percentage range, ranging from 0% to 100% in increments of 10%. These variables were coded using the coding method presented in Table 3.

**Table 3:** Coding method

| T -1, T -2, T -3, T -4, T -5, P -1, P -2, P -3 | | |
|---|---|---|
| 0% - 10% | = | 1 |
| 11% - 20% | = | 2 |
| 21% - 30% | = | 3 |
| 31% - 40% | = | 4 |
| 41% - 50% | = | 5 |
| 51% - 60% | = | 6 |
| 61% - 70% | = | 7 |
| 71% - 80% | = | 8 |
| 81% - 90% | = | 9 |
| 91% - 100% | = | 10 |

The survey questionnaire was developed and published on the internet for respondents to easily complete. The survey questionnaire was comprised of the following sections:

*Section 1: General information* - This section was used to establish the individual profiles of the respondents in terms of current role in the company, experience and technical skills, qualifications.
*Section 2: Choice of modelling method* - This section was used to indicate the type and frequency of modelling methods utilized by respondents.
*Section 3: Factors affecting the choice of modelling method* - This section was used to identify the factors affecting the choice modelling method.
*Section 4: Project Performance* - This section relates to the impact the choice of modelling method has on project performance.

Data entered for section 1 was used to establish the individual profiles of the respondents in terms of current role in the company, experience and technical skills, qualifications. An ordinal five-point Likert-type scale was used for section 3. Data entered for section 2 and 4 of the survey was ordinal discrete variables, indicating a percentage ranging from 0% to 100% in increments of 10%. These variables were coded using the coding method presented in Table 3.

Descriptive statistics are used to form the basis of quantitative analysis of the research and are used to describe the features of the collected data by providing measures of spread, centre and association about the data sample. The Three descriptive measures of a variable that will be evaluated by this research are:
*Distribution:* The summary of frequency of individual variable shall be analysed and depicted on graphs.
*Central tendency:* The mean, median and mode shall be calculated to describe the central tendency of the sample data.
*Dispersion:* Standard deviation shall be used to estimate the dispersion of data.

## 5. RESULTS

### 5.1 Descriptive Analysis

A primary objective of the research was to identify current modelling practices in South Africa for planning/designing of mobile crane lifting operations. In section 2 of the questionnaire survey, respondents were asked to indicate their percentage of utilization for planning of mobile crane lifting operations over the past 5 years for each of the listed modelling methods. The results are shown in Figure 4 and indicate that all modelling methods discussed in the literature are adopted, albeit at different extents in South Africa.

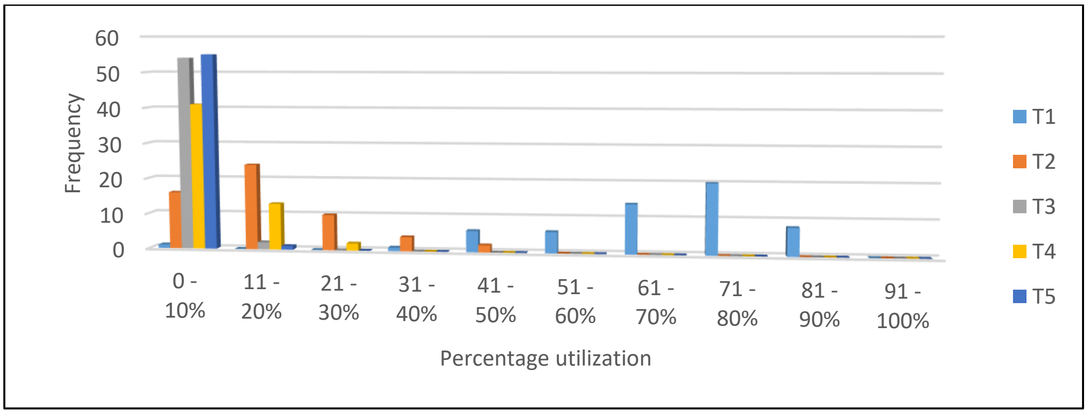


**Figure 4:** Column diagram of the frequency distribution of choice of modelling method

Descriptive features of the data collected from section 2 of the questionnaire survey are presented in Table 4 below. The maximum mean of 7.16 indicates that the majority of respondents utilize static 2D modelling for planning and/or designing mobile crane lifting operations. The low mean values of 1.03, 1.3, and 1.01 for T3, T4, and T5 respectively, indicated a very low utilization rate for these modelling methods among respondents.

**Table 4:** Descriptive statistics for choice of modelling method

| Variable | Description | Mean | Mode | Median | Std Dev |
|---|---|---|---|---|---|
| T-1 | Static 2D Modelling | 7.16 | 8 | 7.5 | 1.51 |
| T-2 | Static 3D Modelling | 2.14 | 2 | 2.0 | 1.03 |
| T-3 | Physical Modelling | 1.03 | 1 | 1.0 | 0.18 |
| T-4 | Virtual Modelling | 1.30 | 1 | 1.0 | 0.53 |
| T-5 | Mathematical Modelling | 1.01 | 1 | 1.0 | 0.13 |

### 5.2 Hypotheses Testing

The hypotheses were investigated using the statistical techniques; correlation and multiple regression analysis.

#### 5.2.1 *Influencing Factors and Choice of Modelling Method*

In order to ascertain the impact of influencing factors on the choice of modelling methods, linear multiple regression analysis was used on the data. The model results are presented in Table 5 below.

**Table 5:** Regression Analysis results captured from Microsoft Excel

| Independent Variable | | Correlation | R² | Slope Coefficient | Slope P-value | t-test | F-test |
|---|---|---|---|---|---|---|---|
| | | **Dependent Variable: Static 2D modelling** | | | | | |
| | | **Regression Analysis Data** | | | | | |
| F1 | Perceived Usefulness | 0.493 | 0.243 | 0.170 | 0.000 | 4.171 | 17.400 |
| F2 | Innovativeness | 0.185 | 0.034 | 0.163 | 0.170 | 1.388 | 1.929 |
| F3 | Subjective Norm | 0.186 | 0.034 | -0.122 | 0.169 | -1.392 | 1.939 |
| F4 | Awareness | 0.460 | 0.212 | 0.145 | 0.000 | 3.814 | 14.547 |
| F5 | Ease of Operation | 0.050 | 0.002 | 0.049 | 0.712 | 0.370 | 0.137 |
| | | **Dependent Variable: Static 3D modelling** | | | | | |
| F1 | Perceived Usefulness | 0.499 | 0.249 | 0.468 | 0.000 | 4.239 | 17.976 |
| F2 | Innovativeness | 0.484 | 0.234 | 0.623 | 0.000 | 4.070 | 16.566 |
| F3 | Subjective Norm | 0.005 | 0.000 | -0.004 | 0.970 | -0.037 | 0.001 |
| F4 | Awareness | 0.512 | 0.262 | 0.483 | 0.000 | 4.389 | 19.267 |
| F5 | Ease of Operation | 0.482 | 0.233 | 0.696 | 0.000 | 4.051 | 16.417 |
| | | **Dependent Variable: Physical modelling** | | | | | |
| F1 | Perceived Usefulness | 0.343 | 0.117 | 1.907 | 0.009 | 2.685 | 7.211 |
| F2 | Innovativeness | 0.195 | 0.038 | 1.388 | 0.149 | 1.463 | 2.14 |
| F3 | Subjective Norm | 0.203 | 0.041 | -1.074 | 0.133 | -1.524 | 2.323 |
| F4 | Awareness | 0.16 | 0.025 | 0.759 | 0.236 | 1.197 | 1.433 |
| F5 | Ease of Operation | 0.162 | 0.026 | 1.296 | 0.231 | 1.211 | 1.467 |
| | | **Dependent Variable: Virtual modelling** | | | | | |
| F1 | Perceived Usefulness | 0.76 | 0.57 | 1.55 | 0.00 | 8.53 | 72.82 |
| F2 | Innovativeness | 0.64 | 0.41 | 1.60 | 0.00 | 6.17 | 38.02 |
| F3 | Subjective Norm | 0.22 | 0.05 | 0.40 | 0.11 | 1.65 | 2.71 |
| F4 | Awareness | 0.80 | 0.64 | 2.24 | 0.00 | 9.78 | 95.69 |
| F5 | Ease of Operation | 0.71 | 0.50 | 1.97 | 0.00 | 7.40 | 54.72 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Dependent Variable: Mathematical modelling | | | | | |
| F1 | Perceived Usefulness | 0.404 | 0.163 | 2.418 | 0.002 | 3.248 | 10.555 |
| F2 | Innovativeness | 0.187 | 0.035 | 1.872 | 0.165 | 1.405 | 1.976 |
| F3 | Subjective Norm | 0.407 | 0.165 | 3.018 | 0.001 | 3.277 | 10.740 |
| F4 | Awareness | 0.479 | 0.229 | 2.436 | 0.000 | 4.015 | 16.121 |
| F5 | Ease of Operation | 0.205 | 0.042 | 2.290 | 0.129 | 1.540 | 2.372 |

The correlation results showed acceptable levels of correlation between certain influencing factors (independent variables) and choice of modelling method (dependant variables). The results indicated a moderately positive correlation (0.34 – 0.499) between perceived usefulness and choice of modelling method for all methods except virtual modelling, where a strong positive correlation (0.76) was observed. Hypothesis H1-1 is therefore supported (t-test > 2.01, F-test > 4.02. P-value < 0.05).

A moderately positive correlation was observed between innovativeness and the utilization of static 3D modelling and virtual modelling. Hypothesis H1-2 is supported for the choice of static 3D modelling and virtual modelling (t-test > 2.01, F-test > 4.02. P-value < 0.05). A weak positive correlation was observed between subjective norm and the choices of modelling, except for mathematical modelling where a moderately positive correlation was observed (0.407). Hypothesis H1-3 is therefore supported for the choice of mathematical modelling (t-test > 2.01, F-test > 4.02. P-value < 0.05).

A moderately positive correlation was observed between awareness and the choice of modelling methods with a very strong positive correlation (0.8) observed for virtual modelling. Hypothesis H1-4 is therefore supported (t-test > 2.01, F-test > 4.02. P-value < 0.05). Ease of operation indicated a moderately positive correlation to static 3D modelling as well as virtual modelling. A moderately positive correlation was observed between Ease of operation and the choice of modelling methods, with a very strong positive correlation (0.7) observed between ease of operation and virtual modelling. Hypothesis H1-5 is therefore supported (t-test > 2.01, F-test > 4.02. P-value < 0.05).

### 5.2.2 *Project Performance and Choice of Modelling Method*

In order to ascertain the impact of choice of modelling method on project performance, linear multiple regression analysis was also used on the gathered data. The model results are presented in Table 6 below.

**Table 6:** Regression Analysis captured in Excel

| | | Dependant Variable: Project Schedule Targets | | | | | |
|---|---|---|---|---|---|---|---|
| | | Regression Analysis Data | | | | | |
| Independent Variable | | Correlation | $R^2$ | Slope Coefficient | Slope P-value | t-test | F-test |
| T1 | Static 2D Modelling | 0.398 | 0.158 | 0.434 | 0.002 | 3.189 | 10.170 |
| T2 | Static 3D Modelling | 0.508 | 0.258 | 0.810 | 0.000 | 4.340 | 18.839 |
| T3 | Physical Modelling | 0.157 | 0.024 | 1.388 | 0.245 | 1.173 | 1.377 |
| T4 | Virtual Modelling | 0.642 | 0.412 | 1.974 | 0.000 | 6.160 | 37.950 |
| T5 | Mathematical Modelling | 0.151 | 0.023 | 1.872 | 0.264 | 1.128 | 1.273 |
| | | Dependant Variable: Project Safety Targets | | | | | |
| T1 | Static 2D Modelling | 0.458 | 0.210 | 0.451 | 0.000 | 3.795 | 14.408 |
| T2 | Static 3D Modelling | 0.464 | 0.215 | 0.667 | 0.000 | 3.854 | 14.853 |
| T3 | Physical Modelling | 0.118 | 0.014 | 0.944 | 0.382 | 0.880 | 0.775 |
| T4 | Virtual Modelling | 0.523 | 0.274 | 1.450 | 0.000 | 4.518 | 20.414 |
| T5 | Mathematical Modelling | 0.129 | 0.016 | 1.436 | 0.342 | 0.956 | 0.915 |
| | | Dependant Variable: Project Customer Satisfaction Targets | | | | | |
| T1 | Static 2D Modelling | 0.364 | 0.132 | 0.363 | 0.005 | 2.871 | 8.248 |
| T2 | Static 3D Modelling | 0.489 | 0.239 | 0.713 | 0.000 | 4.124 | 17.008 |
| T3 | Physical Modelling | 0.209 | 0.043 | 1.685 | 0.121 | 1.572 | 2.471 |
| T4 | Virtual Modelling | 0.575 | 0.331 | 1.617 | 0.000 | 5.172 | 26.756 |
| T5 | Mathematical Modelling | 0.146 | 0.021 | 1.654 | 0.281 | 1.088 | 1.185 |

A moderately positive correlation was observed between the independent variables (static 2D modelling, static 3D modelling, and virtual modelling) and the dependant variables (project performance targets). Results from the regression analysis revealed that the utilization of virtual modelling methods for planning of lifting operations, increased the percentage of projects that met their schedule goals, safety goals, and customer satisfaction goals. Hypotheses H2-1, H2-2, and H2-3 is therefore supported.

# 6 DISCUSSION

The following subsections present summaries of the findings and substantiates the proposed hypotheses which apply only to firms operating in the mobile crane lifting industry in South Africa.

## 6.1 Influencing factors affecting the choice of modelling method

Findings from the research revealed that, a firm's choice of modelling method is strongly influenced by their perceived usefulness towards a specific modelling method. This finding was most applicable to virtual modelling, where a strong positive correlation (0.76) was observed between perceived usefulness and the adoption of virtual modelling. These findings are consistent with Sebastian et al. (2009)'s suggestions that implementing innovative processes involve developing an awareness of the innovation as well as perceiving the need for utilizing/adopting the innovation.

From the literature it is stated that innovativeness of an organisation to have processes in place for introducing new ideas, workflows, methodologies, services, and/or products, is a critical factor for technology adoption (Newton and Chileshe, 2012). Results from the research are consistent with the findings of Newton and Chileshe, (2012). It can therefore be concluded that South African firms holding a competitive advantage in terms of developing and/or implementing new ideas and/or processes in the field of mobile crane operations, have a higher adoption rate for innovative technologies (such as virtual modelling), compared to firms who are not considered market leaders.

The investigation revealed that, except for mathematical modelling, client preference had no noticeable effect on the choice of modelling method. This finding is not consistent with existing literature (Lee et al., 2013). It should be noted that existing literature on client preference as an influencing factor in technology adoption in the construction industry are primarily done in industrialized countries. As the survey was conducted in South Africa, the local environment could potentially influence the results compared to other industrialized countries. This finding suggests that for client preference to have a significant impact, the entire industry value chain needs to collectively adopt and promote modern lift planning practices.

Ease of operation has a positive effect on the adoption of virtual modelling as a modelling method. Further to this, the research revealed that firms who execute more complex lifting operations are more likely to utilize more innovative modelling methods such as virtual modelling. The literature has shown how utilizing innovative modelling methods to simulate mobile crane lifting operations (Han et al., 2015), are improving the performance of complex lifting projects by optimizing crane selection, improving communication among project participants and reducing the turnaround time of project execution. Table 7 below provides a summary the significance of each influencing factor in relation to each modelling method.

## 6.2 Project performance and the choice of modelling method

The second part of this research was aimed at investigating the linkage between the choice of modelling methods and its impact on project performance. Findings from the research revealed that firms utilizing virtual modelling as a planning tool, had a higher success rate with projects achieving their scheduling goals, safety goals, and customer satisfaction goals compared to firms using other methods. These findings are consistent with Han et al., (2015)'s suggestions that virtual modelling improves the turnaround time of lifting projects, helps identify collision risks, and assists with decision making and communication among project participants.

**Table 7:** Influencing factors ranked from most significant to least

| Ranking | Modelling Method | | | | |
|---|---|---|---|---|---|
| | Static 2D Modelling | Static 3D Modelling | Physical Modelling | Virtual Modelling | Mathematical Modelling |
| 1 | F1 - Perceived Usefulness | F4 - Awareness | F1 - Perceived Usefulness | F4 - Awareness | F4 - Awareness |
| 2 | F4 - Awareness | F1 - Perceived Usefulness | | F1 - Perceived Usefulness | F3 - Subjective Norm |
| 3 | F6 - Ease of Maintenance | F2 - Innovativeness | | F5 - Ease of Operation | F1 - Perceived Usefulness |
| 4 | | F5 - Ease of Operation | | F2 - Innovativeness | |

## 7 CONCLUSIONS AND RECOMMENDATIONS

This research proposed a conceptual framework to evaluate current modelling practices applied in South Africa for mobile crane lifting operations. The framework was used to:

- Investigate current adoption levels for the different types of modelling methods in South Africa.
- Identify the influencing factors affecting the choice of modelling methods used by firms in South Africa for planning and/or designing of mobile crane lifting operations.
- To investigate the linkage between the choice of modelling methods and the impact it has on the performance of mobile crane lifting projects in South Africa.

The results concluded that existing literature and theories do indeed apply to some of the hypotheses and propositions put forward by this investigation which applies to mobile crane lifting related projects in South Africa.

Previous studies have shown how the utilization of advanced modelling technologies for lift planning activities offer advantages to mobile crane lifting operations as project key performance indicators such as safety, production, and customer satisfaction can be optimized, thereby offer customers a significant leap in value and user a competitive advantage. The research revealed that most of the mobile crane operations executed in South Africa are still being planned/designed using outdated static 2D modelling methods.

Findings from the research revealed that, a firm's choice of modelling method is strongly influenced by their perceived usefulness towards a specific modelling method as well as the awareness of a firm regarding the applications and benefits of a specific technology type. This finding was most applicable to virtual modelling, where a strong positive correlation was observed between perceived usefulness (0.76) and awareness (0.8) to the adoption of virtual modelling.

Findings from the research revealed that firms utilizing advanced modelling methods such as virtual modelling, had a higher success rate with projects achieving their scheduling goals, safety goals, and customer satisfaction goals.

### 7.1 Research implications

This research helped to identify which factors affect the choice of modelling methods for lift planning and how these chosen methods affect the performance of projects executed by firms operating in the mobile crane lifting industry in South Africa. Adoption of innovation in mobile crane lift planning (i.e., virtual modelling) was identified as a key driver for project success and ultimately business competitiveness. From Table 7, the two most significant factors influencing firms in adopting virtual modelling was found to be Awareness and Perceived usefulness. It is therefore imperative that firms operating in the mobile crane lifting industry ensure that they invest in the adoption of innovative modelling methods for planning of mobile crane lifting operations.

Failure to adopt innovation in this field could have long term negative consequences which could negatively impact a firm's market share. As global trends are set to continue to shift to modularization, increased performance of optimized crane operations on site will become critical to both project and company success. Given these trends, firms who are resistant/slow to adopt innovations in lifting operations, will likely face reduced market share, or even extinction (as history has shown with many other industries such as for example, newspaper printing industries) in a rapidly occurring 4th industrial revolution.

### 7.2 Limitations and assumptions of this study

The assumptions of this study were:

*Financial factors*: It was assumed that local firms in the mobile crane industry would be reluctant to supply information regarding the financial aspects of current practices in lift planning as well as potential financial implications of the proposed methodologies for this research. Thus, the economic implications were not covered in this research.

*Response*: An assumption was made that responses to the questionnaires would be truthful and accurate to give an accurate view on current practices and challenges associated with planning of lifting operations within the local South African industry.

The limitations of this study were:

*Sample size*: The research was limited to the mobile crane-related industry in South Africa. Furthermore, it was limited to a population group comprising of predominantly designers and planners of lifting operations within this industry, which limited the study group.

*Time frame:* The study was limited by the fourteen-month time frame that was allocated to it, which limited the scope of study that could be covered.

*Method of data collection:* It was not practical for the researcher to physically access all relevant industry companies and personnel. Due to this limitation, data had to be collected using a survey-questionnaire method. This method of data collection also adds limitations on the research as factors such as low response rate can affect the validity of the research findings.

### 7.3 Recommendations

It is recommended that futures studies should focus on identifying the constraints within the South African mobile crane industry that hinders the upskilling and training of relevant staff members in firms, as internal skills and capabilities of a firm are critical factors for successful adoption of innovative modelling techniques. Furthermore, future research should investigate the factors preventing South African firms from adopting innovative modelling practices and how the findings from this research could be used by key decision makers to adopt their business strategies to benefit from the global emerging trends of off-site construction methods.

There is a further need to link this modelling method selection to a project management process, such as the phase-gate process. For projects where a significant amount of material handling and lifting activities will occur, a lifting specialist should ideally form part of the project team during the pre-construction phase of a project. During this phase, the lifting specialist must do proper pre-construction engineering activities to be able to assess the material handling and lifting requirements, to optimize the trade-offs between design, construction, and lifting activities.

## REFERENCES

Aber, J. S., et al. (2010). Chapter 3 - Photogrammetry. Small-Format Aerial Photography. J. S. Aber, I. Marzolff and J. B. Ries. Amsterdam, Elsevier: 23-39.
Akbarnezhad, A. (2016). Factors Influencing BIM Adoption in Small and Medium Sized Construction Organizations. Proceedings of the 33rd International Symposium on Automation and Robotics in Construction (ISARC), International Association for Automation and Robotics in Construction (IAARC): 452-461.
An, J., et al. (2018). Re-optimization strategy for truck crane lift-path planning. Automation in Construction 90: 146-155.
Bang, S., et al. (2017). UAV-based automatic generation of high-resolution panorama at a construction site with a focus on preprocessing for image stitching. Automation in Construction 84: 70-80.
Bouchlaghem, D., et al. (2005). Visualisation in architecture, engineering and construction (AEC). Automation in Construction 14(3): 287-295.
Cantot, P. and D. Luzeaux (2013). Simulation and Modeling of Systems of Systems, Wiley.
Chi, H.-L. and S.-C. Kang (2010). A physics-based simulation approach for cooperative erection activities. Automation in Construction 19(6): 750-761.
Du, J.-C. and H.-C. Teng (2007). 3D laser scanning and GPS technology for landslide earthwork volume estimation. Automation in Construction 16(5): 657-663.
ElNimr, A., et al. (2016). Two-way integration of 3D visualization and discrete event simulation for modeling mobile crane movement under dynamically changing site layout. Automation in Construction 68: 235-248.
Eschmann, C., et al. (2012). Unmanned aircraft systems for remote building inspection and monitoring. Proceedings of the 6th European Workshop on Structural Health Monitoring, Dresden, Germany: 36.
George, S., et al. (2019). Towards Drone-sourced Live Video Analytics for the Construction Industry. Proceedings of the 20th International Workshop on Mobile Computing Systems and Applications - HotMobile '19: 3-8.
Gheisari, M. and B. Esmaeili (2019). Applications and requirements of unmanned aerial systems (UASs) for construction safety. Safety Science 118: 230-240.
Gledson, B., et al. (2012). Does size matter? Experiences and perspectives of BIM implementation from large and SME construction contractors.
Han, S. H., et al. (2015). Utilization of 3D Visualization of Mobile Crane Operations for Modular Construction On-Site Assembly. Journal of Management in Engineering 31(5).
Hornaday, W. C., et al. (1993). Computer Aided Planning for Heavy Lifts. Journal of Construction Engineering and Management 119(3): 498-515.
Hsu, P.-Y., et al. (2018). Optimal logistics planning for modular construction using two-stage stochastic programming. Automation in Construction 94: 47-61.
Huang, C., et al. (2011). Optimization of tower crane and material supply locations in a high-rise building site by mixed-integer linear programming. Automation in Construction 20(5): 571-580.
Jalali Yazdi, A., et al. (2018). Mathematical model to optimally solve the lift planning problem in high-rise construction projects. Automation in Construction 92: 120-132.
Jiang, W., et al. (2020). UAV-based 3D reconstruction for hoist site mapping and layout planning in petrochemical construction. Automation in Construction 113.
Joshi, A., et al. (2015). Likert Scale: Explored and Explained. British Journal of Applied Science and Technology 7: 396-403.
Khaloo, A., et al. (2017). Unmanned aerial vehicle inspection of the Placer River Trail Bridge through image-based 3D modelling. Structure and Infrastructure Engineering 14(1): 124-136.
Kim, D., et al. (2019). Remote proximity monitoring between mobile construction resources using camera-mounted UAVs. Automation in Construction 99: 168-182.
Koo, B. and M. Fischer (2000). Feasibility study of 4D CAD in commercial construction. Journal of Construction Engineering and Management 126(4): 251-260.
Koshy Varghese, P. D., John Wolfhope, James T.O'Connor (1997). A heavy lift planning system for crane lifts. Microcomputers in civil engineering 12: 31-42.

Krejcie, R. V. and D. W. Morgan (1970). Determining Sample Size for Research Activities. Educational and Psychological Measurement 30(3): 607-610.
Law, A. M., et al. (2000). Simulation modeling and analysis, McGraw-Hill New York.
Lee, S.-K., et al. (2013). BIM Acceptance Model in Construction Organizations. Journal of Management in Engineering 31: 04014048.
Lien, L.-C. and M.-Y. Cheng (2014). Particle bee algorithm for tower crane layout with material quantity supply and demand optimization. Automation in Construction 45: 25-32.
Liu, C.-W., et al. (2018). Image-based semantic construction reconstruction. Automation in Construction 90: 67-78.
Manrique, J. D., et al. (2007). Constructing a complex precast tilt-up-panel structure utilizing an optimization model, 3D CAD, and animation. Journal of Construction Engineering and Management 133(3): 199-207.
Marzouk, M. and A. Abubakr (2016). Decision support for tower crane selection with building information models and genetic algorithms. Automation in Construction 61: 1-15.
Montgomery, D. C. R., G.C.; Norma, F.H. (1998). Engineering Statistics. New York, Wiley.
Moselhi, O., et al. (2004). Innovative 3D-modeling for selecting and locating mobile cranes. Engineering Construction and Architectural Management 16: 212-223.
Negnevitsky, M. (2005). Artificial intelligence: a guide to intelligent systems, Pearson education.
Newton, L. and N. Chileshe (2012). Awareness, usage and benefits of building information modelling (BIM) adoption-the case of South Australian construction organizations.
Olearczyk, J., et al. (2008). Interactive 4D modeling for modular building construction. Proceedings, Annual Conference - Canadian Society for Civil Engineering.
SangHyeok. Han, S. H., Mohamed. Al-Hussein, Kamil. Umut (2012). Simulation of mobile crane operations in 3D space. Proceedings of the 2012 winter simulation conference.
Sebastian, R., et al. (2009). BIM application for integrated design and engineering in small-scale housing development: a pilot project in The Netherlands. 2-3.
Sivakumar, P. L., et al. (2003). Automated path planning of cooperative crane lifts using heuristic search. Journal of Computing in Civil Engineering 17(3): 197-207.
Son, H., et al. (2012). Toward an understanding of construction professionals' acceptance of mobile computing devices in South Korea: An extension of the technology acceptance model. Automation in Construction 28: 82–90.
Song, L. and S. M. AbouRizk (2006). Virtual Shop Model for Experimental Planning of Steel Fabrication Projects. Journal of Computing in Civil Engineering 20(5): 308-316.
Taghaddos, H., et al. (2018). Automated Crane Planning and Optimization for modular construction. Automation in Construction 95: 219-232.
Tam, C. M., et al. (2002). Nonlinear models for predicting hoisting times of tower cranes. Journal of Computing in Civil Engineering 16(1): 76-81.
Tantisevi, K. and B. Akinci (2007). Automated generation of workspace requirements of mobile crane operations to support conflict detection. Automation in Construction 16(3): 262-276.
Walonick, D. (2010). Survival statistics. Bloomington: Statpac.
Whyte, J., et al. (2000). From CAD to virtual reality: modelling approaches, data exchange and interactive 3D building design tools. Automation in Construction 10(1): 43-55.
Wu, K., et al. (2020). Spatio-temporal planning for tower cranes in construction projects with simulated annealing. Automation in Construction 111.
Younes, A. and M. Marzouk (2018). Tower cranes layout planning using agent-based simulation considering activity conflicts. Automation in Construction 93: 348-360.
Zhang, Z. and W. Pan (2019). Virtual reality (VR) supported lift planning for modular integrated construction (MiC) of high-rise buildings. HKIE Transactions 26(3): 136-143.
Zhang, Z. and W. Pan (2020). Lift planning and optimization in construction: A thirty-year review. Automation in Construction 118.

Journal of Construction Project Management and Innovation, 12(1): 17-33, 2022
ISSN 2223-7852


# COVID-19-related factors affecting construction labour productivity in Zimbabwe

**Benviolent Chigara[1] and Tirivavi Moyo[2]**

[1]Department of Property Studies and Urban Design, National University of Science and Technology, Bulawayo, Zimbabwe
[2]Department of Quantity Surveying, Nelson Mandela University, South Africa

Email: benviolent.chigara@nust.ac.zw; Tirivavi.moyo@mandela.ac.zw

## ABSTRACT
The COVID-19 pandemic aggravated the underlying productivity challenges in the construction sector. However, not much is known regarding how the pandemic affected labour productivity in developing countries such as Zimbabwe. Therefore, this study investigates the COVID-19-related factors affecting construction labour productivity in Zimbabwe. A survey design entailed the distribution of an online questionnaire to construction professionals in Bulawayo and Harare. The data was analyzed using descriptive statistics. Factor analysis was also utilized to reveal significant factors affecting construction labour productivity. Factor analysis revealed nine (9) significant factors contributing to reduced labour productivity during the COVID-19 pandemic, namely: poor project planning and management issues; permits and inspection delays; cash flow and payment challenges; compliance with COVID-19 health and safety (H&S) protocols; disruption of project activities; lack of empowerment and capacity building; material supply disruptions; labour supply disruptions; and design changes and poor information transfer. Construction stakeholders can use the results of this study to design appropriate interventions to prevent/reduce pandemic-related productivity losses. However, differences in insights due to demographic variables were not determined to enable targeted interventions. This study is among the emerging studies investigating how the COVID-19 pandemic affected construction labour productivity from a developing country perspective, with the consequent determination of appropriate interventions envisaged.

**Keywords:** COVID-19, factors, construction productivity, Zimbabwe

## 1. INTRODUCTION
Increasing labour productivity in construction is crucial for realizing the economic growth and sustainability of the construction business. In the construction sector, where most projects are labour-based, productivity growth is crucial to enhance project performance. Kapsos (2021) observes that labour productivity growth enhances business profitability. According to Dozzi and AbouRizk (1993), labour efficiency is the basis of most tender estimates and is used to measure and monitor performance. Despite the crucial place of labour productivity in enhancing project and business performance, the construction industry is characterized by a systemic labour productivity challenge (Adebowale and Agumba, 2021; Chigara and Moyo, 2014). As summarized by Adebowale and Agumba (2021), construction labour productivity has fallen behind other industries in most countries and has declined continuously for decades. The challenge is exacerbated by the coronavirus disease of 2019 (COVID-19) (McLin et al., 2020; Rubin, 2020).

COVID-19 is an infectious disease which was first discovered in Wuhan Province in China in December 2019. It was declared a public health emergency by the World Health Organisation (WHO) on 11 March 2020 (ILO, 2020). The COVID-19 pandemic has an enormous social and economic burden on society, workers and enterprises. As of 20

December 2021, 276,366,657 people had been infected, and 5,372,513 had died globally (Johns Hopkins University, 2021). Zimbabwe recorded 195,079 COVID-19 infections and 4,805 deaths (Ministry of Health and Childcare, 2021). To preserve public health and protect workers' H&S, the Government of Zimbabwe, in consultation with the WHO, adopted several measures such as the closure of national borders, the shutdown of main economic activities, restricted movement and gatherings, the introduction of additional public health protocols such as social distancing and handwashing (Chigara and Moyo, 2021a).

Nonetheless, essential construction activities such as rehabilitation of hospitals and infrastructure were allowed to continue under COVID-19-induced protocols and conditions (McLin et al., 2020; Chigara and Moyo, 2021a). However, the radical shifts introduced in the organization of work to limit the spread of the virus had several ramifications for construction labour productivity. In the United Kingdom (UK), Rubin (2020) established that the pandemic and response efforts caused labour productivity losses of around 35%. In the United States of America (USA), McLin et al. (2020) report that construction labour productivity was impacted by nearly 20% because of the COVID-19 pandemic. Related studies conducted in Jordan (Bsisu, 2020), the USA (Alsharef et al., 2021) and Zimbabwe (Chigara and Moyo, 2021b) affirm the adverse effect of COVID-19 on construction labour productivity. Economically, a reduction in labour productivity adversely affects overall project performance through its impact on project schedules and project costs (King and Rahman, 2021; Rahman et al., 2021).

Given the potential impact of COVID-19 on construction labour productivity, McLin et al. (2020) and Rubin (2020) quantified the magnitude of productivity loss. While these studies are crucial to demonstrate the magnitude of the problem, Enshassi et al. (2007) argue that improving labour productivity requires understanding the drivers of productivity loss. However, studies investigating the significant drivers of construction labour productivity loss during the COVID-19 pandemic in Zimbabwe and other developing countries remain limited. Therefore, this study sought to bridge this gap by investigating the perceptions of construction professionals in Zimbabwe regarding the COVID-19-related factors affecting labour productivity. Furthermore, given the recurrence of pandemics and the uncertainty surrounding the COVID-19 pandemic, knowledge of the factors affecting labour productivity during this pandemic is critical to inform construction stakeholders and policymakers regarding interventions required to promote productivity growth in construction during and after the pandemic.

## 2. THE REVIEW OF RELATED LITERATURE

This section will present the study's theoretical background under the following subheadings.

### 2.1 Overview of covid-19 control measures in construction

COVID-19 is an infectious disease caused by SARS-COV-2 (American Industrial Hygiene Association, AIHA, 2020). It spreads rapidly through airborne exposure (AIHA, 2020) when a person comes into close contact (within 2m) with an infected person and indirectly through contact with a surface recently contaminated with respiratory droplets (Workplace Health and Safety Queensland, 2020; WHO, 2020). The risk of COVID-19 infection in construction is amplified by the nature of work which calls for workers to work in close contact and share common spaces such as elevators, lunch and break areas, and sanitation facilities (AIHA, 2020). An emerging body of evidence shows that construction workers have a higher risk of COVID-19 infection than workers in other sectors (Allan-Blitz et al., 2020; Alsharef et al., 2021; Pasco et al., 2020). The risk of serious illness is also high in individuals with underlying health conditions and those above 60 years (ILO, 2020). McLin et al. (2020) estimate that a 10% impact on productivity results in a 100% impact on profitability.

To limit the spread of COVID-19 infections, several interventions were introduced at national and sectoral levels. At the national level, measures such as the closing of national borders, the shutdown of primary economic activities, restrictions on movement and large gatherings, quarantine procedures for infected workers, and the introduction of additional public health protocols such as social distancing and handwashing were adopted (Chigara and Moyo, 2021a). Furthermore, the promulgation of Statutory Instrument 77 of 2020: Public Health (COVID-19 Prevention, Containment, and Treatment) Regulations provided the legal force to enforce the implementation of these measures. In addition, the government spearheaded the COVID-19 vaccination programme. At the sector level, the construction industry adopted several measures including implementation of social distancing requirements, health screening of workers and provision of personal protective equipment (PPE), amongst others. While these measures are essential to limit the spread of the virus, notable shortcomings in the implementation of the measures, distribution of vaccines, and potential waning of vaccine efficacy against new COVID-19 variants suggest that the world is far from reverting to normalcy. This calls for the continuation of some public health measures to limit the spread of the virus and its effects on workers and the public.

## 2.2 Construction labour productivity

Labour productivity contributes immensely to the realization of project objectives in construction (Chigara and Moyo, 2014). However, there is a surfeit of evidence identifying low labour productivity among the key challenges affecting construction projects (Enshassi et al., 2007; Chigara and Moyo, 2014). According to Kapsos (2021), productivity is a measure of how efficiently inputs such as labour, capital, land, energy, and other intangible factors are used to produce goods and services. Therefore, labour productivity is a crucial element of construction productivity. A fall in labour productivity can adversely affect project performance by influencing project duration and cost. Van Biesebroeck (2015) define labour productivity as the value of output that a worker, a firm, an industry, or a country has produced per unit of labour input. In the long term, improving labour productivity is critical to improving the economic development of project performance, firm competitiveness and profitability, and standard of living (Kapsos, 2021). Despite this, the construction sector is characterized by a systemic challenge of declining labour productivity due to several factors/challenges. The COVID-19 pandemic is a new challenge to construction labour productivity. Understanding the various pathways/channels through which the pandemic affects labour productivity is critical to developing strategies to reduce inefficiencies and more effectively manage construction labour (Hamza et al., 2019). While several studies have been conducted to identify factors affecting construction labour productivity, only a few have addressed the labour productivity challenge during the COVID-19 pandemic. Since improving labour productivity is a concern for any profit-oriented business (Enshassi et al. 2007), knowledge of the factors affecting labour productivity during the COVID-19 pandemic is essential to identify key focus areas to foster productivity growth during and after the pandemic.

## 2.3 The impact of covid-19 on construction labour productivity

Emerging evidence suggests that the COVID-19 pandemic aggravated the labour productivity challenge in the construction industry. To limit the spread of the disease on construction sites, radical shifts were introduced directed at work organization. These measures had concomitant effects on labour productivity. Chigara and Moyo (2021b) report that the stringent measures adopted to limit the spread of the virus reduced construction labour productivity between a near major to a major/major extent. During another study in the USA, Alsharef et al. (2021) established that the pandemic contributed to a significant reduction in productivity rates in the construction industry.

King et al. (2021) examines the critical pandemic impacts (CPI) on the architecture, engineering and construction (AEC) organizations using a systematic literature review and in-depth interviews with 40 AEC practitioners. The study reports that the pandemic and response efforts reduced construction productivity. In Ghana, Amoah et al. (2021) investigated the impact of COVID-19 on small construction firms using open-ended questionnaires administered to 30 respondents from selected firms. The study's main findings are that workers' productivity levels dwindled and consequently escalated project costs and completion time. A related study conducted in the construction industry in Vietnam reveals that COVID-19 adversely affected construction labour productivity (Nguyen et al., 2021). In another study in the UK, Rubin (2020) observes that the COVID-19 pandemic generated productivity losses amounting to 35% on construction projects. Finally, using a case study of 45 projects implemented during the pandemic in the UK, the Construction Manager (2020) reports that the COVID-19 pandemic caused extra productivity losses of around 15% on UK construction sites.

The COVID-19 pandemic affected construction labour productivity in various ways. According to Rubin (2020), the pandemic affected labour productivity through labour and material disruptions, social distancing requirements, poor transfer of design information while remote working and poor planning. In a related study in the UK, the Construction Manager (2020) reports that labour shortages, the impact of social distancing, poor transfer of design information while remote working, late deliveries, delays in the arrival of domestic materials, and poor planning and inefficiency were the main factors accounting to productivity losses.

Bloom et al. (2020) investigates the impact of COVID-19 on productivity in the UK. The findings of the study reveal that the pandemic reduced total factor productivity by 5% in the fourth quarter of 2020. The authors observe that the re-organization of production processes in response to the pandemic shock has implications for productivity and factor usage. McLin et al. (2020) examine the impact of the pandemic on the productivity of field and office personnel in the USA. The results indicate that contractors experienced an 8.9% productivity loss due to pandemic mitigation activities. McLin et al. (2020) argue that the time lost complying with the COVID-19 protocols could be devoted to production activities. The job-site pandemic mitigation measures to limit exposure to the virus, such as training, health screenings, cleaning and disinfecting, job site access and administration, significantly affected labour productivity (McLin et al., 2020). In a related study, investigating the impact of the COVID-19 pandemic on civil engineers, Bsisu (2020) states that approximately 32% of the surveyed engineers experienced a decrease in productivity attributed to work-from-home (WFH) arrangements.

Agyekum et al. (2021) adopted a case study design to investigate the impact of COVID-19 on the construction sector in Ghana by conducting nine interviews with professionals from selected firms. The findings of this study reveal that the pandemic affected the working rate and productivity due to the need to comply with H&S protocols relative to COVID-19, such as social distancing. In Malaysia, King et al. (2021) points out that a reduction in labour productivity is the leading critical impact of the COVID-19 pandemic on the AEC sector. The study identified social distancing requirements, labour shortages, poor transfer of information from remote working, and late delivery or unavailable materials due to disruptions in global supply chains as the leading factors contributing to reduced labour productivity.

Quezon and Ibanez (2021) use a survey design among construction professionals in road construction implementation to identify significant factors contributing to low construction labour productivity during the period December 2020 and 31 January 2021 in the Philippines. The main findings of this study suggest that the absence of health workers on construction sites, lack of safety engineers, schedule compression, lack of labour safety standard practice, and lack of empowerment (training/seminar) were the leading factors contributing to low labour productivity during the pandemic. In the USA, Alsharef et al. (2021) studied the early impacts of COVID-19 on the construction industry using interviews with 34 construction professionals. The study reports that COVID-19 contributed to a fall in productivity in the construction industry because of delays in the supply of materials, inspection delays, shortage of materials, PPE shortages, safety prioritized over productivity, workforce reduction per social distancing requirements, worker absenteeism, staggering of work operations, revisions to the original schedule, additional coordination efforts, cash flow and payment challenges, material delays and availability, and inspection and permitting delays as some factors contributing to reduced efficiency and productivity rates (Alsharef *et al.*, 2021). In Ghana, Amoah et al. (2021) examine the impact of COVID-19 on small construction firms. The results of the study reveal that workers experienced a fall in productivity because of stay-at-home mandates for workers, safety screening requirements for the few workers allowed on-site, employees showing up late for work because of transport challenges, and absenteeism of workers because of the fear of contracting the virus.

Table 1 presents a summary of the COVID-19-related factors affecting labour productivity in construction.

**Table 1:** COVID-19-related factors affecting construction labour productivity

| Author | Country | Research method adopted | Insights on the COVID-19-related factors affecting labour productivity |
|---|---|---|---|
| Agyekum et al. (2021) | Ghana | Interviews | Compliance with COVID-19 H&S protocols |
| Rubin (2020) | UK | Literature review | Labour supply disruptions<br>Late delivery or unavailability of materials<br>Social distancing requirements<br>Poor transfer of design information<br>Poor planning. |
| The Construction Manager (2020) | UK | Case study | Labour shortages<br>Poor transfer of design information<br>Late deliveries of materials<br>Poor planning |
| Bsisu (2020) | Jordan | Surveys | Work from home (WFH) arrangement |
| Bloom et al. (2020) | UK | Surveys | Re-organization of production processes |
| McLin et al. (2020) | USA | Survey | Job site pandemic mitigation measures |
| Alsharef et al. (2021) | USA | Interviews | Delays in supply of materials<br>Shortage of materials<br>Inspection delays<br>Prioritization of H&S over productivity<br>Reduced workforce per social distancing requirements<br>Absenteeism of workers<br>Staggering work operations<br>Revisions to the original schedule<br>Cash flow and payment challenges |
| Amoah et al. (2021) | Ghana | Open-ended questionnaire | Stay at home mandates<br>Safety screening requirements on site,<br>Workers showing up late at work because of transport challenges<br>Absenteeism of workers |
| Quezon and Ibanez (2021) | Philippines | Survey | Absence of health workers on construction sites<br>Schedule compression<br>Lack of labour safety standard practice<br>Lack of empowerment (training/seminar). |

Table 1 summarises the channels through which the pandemic and response efforts affected construction labour productivity. While these studies provide essential building blocks for construction stakeholders to respond to the effects of the pandemic, the studies are still very few to provide a complete understanding of the significant challenges affecting construction labour productivity. In addition, the geographical distribution of the studies is skewed toward the developed world, while fewer studies have been conducted in Southern Africa, specifically Zimbabwe. During an earlier study, Hamza et al. (2019) observed that studies on construction labour productivity are biased towards Asia (58%), North America (15%), Europe (13%), and Africa (10%). Therefore, this study sought to expand the boundaries of knowledge on this subject from a developing country's perspective by investigating the perceptions of construction professionals in Zimbabwe regarding the COVID-19-related factors affecting labour productivity. This is consistent with the realization that different countries' varying social, political, and legislative environments call for country-specific studies to inform country-specific interventions.

## 3. RESEARCH METHOD

A survey research design was adopted in which an online questionnaire was distributed to construction professionals selected from contractors and consulting firms based in Bulawayo and Harare. A survey research design is preferred because it provides a quantitative description of the attitudes or opinions of a population by studying a sample of that population (Creswell and Creswell, 2018). The 2020 database of construction and consultant firms shows that over 80% of registered contractors and consulting firms in Zimbabwe are located in the two cities.

*The population and sample* - The population comprises architects, quantity surveyors, civil engineers, construction/project managers, and construction H&S managers. The total population is one hundred and eighty-six (186) firms distributed as 67 contractors in categories A, B, and C (medium to large), 54 Architects, 43 Engineers and 22 Quantity Surveyors. The selected respondents were members of the Construction Industry Federation of Zimbabwe (CIFOZ), Institute of Architects Zimbabwe (IAZ), Zimbabwe Association of Consulting Engineers (ZACE) or Zimbabwe Institute of Quantity Surveyors (ZIQS). Given the lack of a professional body representing construction project managers in Zimbabwe, the study adopted Walker's (2015) advice that project managers for building projects may be drawn from any of the professions associated with construction. Considering that the population is relatively small, a census was adopted in selecting respondents.

*Questionnaire design and administration* - Given the COVID-19 restrictions on movement, an online questionnaire hosted on the Survey Monkey platform was used to collect primary data for the study. An online questionnaire can be accessed from home or office (Bloom et al., 2020) and has low administration costs and is flexible regarding how the questions are displayed (O'Leary, 2017). Conversely, online surveys suffer from a low response rate (O'Leary, 2017). The questionnaire had two sections. The first section required respondents to record their demographic and socio-economic data, such as designation, education, gender, and work experience. The second section comprised a closed-ended question where respondents were asked to rate, on a five-point Likert scale (1 = minor, 2 = near minor, 3 = moderate, 4 = near major, and 5 = major), the extent to which COVID-19 related factors adversely affected construction labour productivity in Zimbabwe. A five-point Likert scale was used because it maintains the response categories meaningful to respondents (Losby and Wetmore, 2012).

Before distributing the questionnaires, five construction experts were invited to review the questionnaire in terms of (a) the ability of the questions to generate the type of information they are required to collect; and (b) relevance and adequacy of the literature-generated COVID-19 related factors with a negative effect on construction labour productivity. The experts were purposively selected from academia (2) and the construction industry (3) based on their knowledge of questionnaire design, experience in the industry (>10 years), and academic qualifications (Master's degree in construction/built environment-related qualification) (Feil and Khan, 2015). The final questionnaire incorporated reviewers' comments and was distributed via emails and on platforms of construction professionals with a web link to a survey. The survey was open between 25 November 2020 and 15 December 2020, and gentle reminders were sent to respondents after a week from the date the survey was first distributed.

*Data analysis* - The Statistical Package for Social Sciences (SPSS) software (24.0) was used for data capturing and statistical analysis. The data was initially analyzed through descriptive statistics, such as computing measures of central tendency in the form of mean scores (MSs) and frequencies to facilitate the ranking of the factors. Through ranking of the variables, the most significant factors were identified, which could help to develop recommendations (Raoufi and Fayeki, 2021). As guided by Ikediashi et al. (2012), a midpoint score of 3.00 [(1+2+3+4+5)/5 = 3)] was used to identify significant factors. The standard deviation was used to facilitate rank differentiation where two or more factors had the same MS (Doloi et al., 2012). Cronbach's alpha was used to assess the internal consistency reliability of the Likert-type scale of the questionnaire. A Cronbach's alpha coefficient ranges from 0.0 to 1.0, and the closer the coefficient to 1.0, the greater the internal consistency of the items in the scale (Gliem and Gliem, 2003). Exploratory factor analysis was used to reveal greater insight among several correlated but seemingly unrelated attributes into fewer underlying factors (Doloi et al., 2012).

## 4. RESULTS AND DISCUSSIONS

### 4.1 Sample stratum and response rate

One hundred and eighty-six (186) questionnaires were distributed, and fifty-five (55) were returned, representing a 29.6% response rate. The response rate is consistent with the observations of earlier studies that the response rate for questionnaire surveys in construction ranges from 20 to 30% (Akintoye and Fitzgerald, 2000). Notably, scholars consider a sample of 30 to be adequate for statistical analysis and making meaningful conclusions (O'Leary, 2017). In addition, the demographic characteristics of the respondents, such as designation, experience, and qualifications, suggest that the study benefited from experienced and knowledgeable respondents and the results provide valuable and important insights which can inform policy and practice to reduce the impact of the pandemic on the sector and particularly labour productivity.

The demographic analysis shows that male respondents were 78.9% while female respondents constituted 21.2%. The gender distribution is consistent with the ZimStat (2019) survey; where females constitute 11.8% of wage/paid employment in the non-agricultural sector. In terms of educational qualifications, the analysis shows that 50.9% of the respondents had an Honours degree, 38.2% with a Master's degree, 7.3% with a National Diploma, and 3.6% with a Higher National Diploma. Regarding the designation, 32.7% of the respondents were Project/Construction Managers, followed by Quantity Surveyors (29.1%) and Engineers (16.4%). The respondents were selected from Contractors (38.8%) and consulting firms: Architects (9.1%), Engineers (16.4%), Project Managers (14.5%) and Quantity Surveyors (21.8%).

**Table 2:** Demographic profile of respondents

| **Characteristic** | **Description** | **Frequency** | **Per cent (%)** |
|---|---|---|---|
| Gender | Male | 43 | 78.2 |
| | Female | 12 | 21.8 |
| | **Total** | **55** | **100** |
| Educational background | Bachelors' degree | 28 | 50.9 |
| | Master's degree | 21 | 38.2 |
| | Higher national diploma | 2 | 3.6 |
| | National Diploma | 4 | 7.3 |
| | **Total** | **55** | **100** |
| Nature of organization | Architects | 5 | 9.1 |
| | Contractors | 21 | 38.2 |
| | Engineers | 9 | 16.4 |
| | Project managers | 8 | 14.5 |
| | Quantity surveyors | 12 | 21.8 |
| | **Total** | **55** | **100** |
| Respondents' profession/ Designation / Role | Director/Partner /Chief Executive Officer | 7 | 12.7 |
| | Project Manager | 18 | 32.7 |
| | Health and Safety Officer / Manager | 2 | 3.6 |
| | Quantity Surveyor | 16 | 29.1 |
| | Architect | 3 | 5.5 |
| | Engineer | 9 | 16.4 |
| | **Total** | **55** | **100** |
| Number of years working in the construction industry | 0 - 5 Years | 11 | 20.0 |
| | 6 -10 Years | 20 | 36.4 |
| | 11 - 15 Years | 17 | 30.9 |
| | > 15 Years | 7 | 12.7 |
| | **Total** | **55** | **100** |

## 4.2 Reliability of the scales

Before conducting statistical analysis, reliability analysis for the 36 factors was conducted. A Cronbach's alpha of 0.945 was obtained. Given that Cronbach's alpha is greater than the minimum threshold value of 0.70 (Hair *et al.*, 2010), the scale can be considered reliable.

## 4.3 COVID-19 related factors affecting construction labour productivity

Table 3 presents the COVID-19-related factors affecting labour productivity in the construction sector in Zimbabwe.

**Table 3:** COVID-19-related factors affecting construction labour productivity in Zimbabwe

| **Factors** | **MS** | **SD** | **Rank** |
|---|---|---|---|
| Disruptions of the global supply of materials | 4.60 | 0.78 | 1 |
| Shortage of materials in the domestic market | 4.51 | 0.77 | 2 |
| Inadequacies of public transport systems | 4.49 | 0.74 | 3 |
| Travel restrictions limiting personnel availability | 4.35 | 0.87 | 4 |
| Delays in the delivery of materials | 4.33 | 0.92 | 5 |
| Delays in issuing permits | 4.23 | 1.05 | 6 |
| Changes in regulations (e.g., the introduction of curfews) | 4.20 | 1.01 | 7 |
| Late payment of salaries and wages | 4.13 | 1.04 | 8 |
| Complying with COVID-19 mitigation measures | 4.09 | 1.08 | 9 |

| | | | |
|---|---|---|---|
| Reduced working hours | 4.09 | 1.21 | 10 |
| Low remuneration | 4.07 | 0.94 | 11 |
| Disruptions of the global supply of equipment | 4.07 | 1.07 | 12 |
| Work stoppages / disruptions | 4.02 | 1.13 | 13 |
| Temporary project suspension | 4.00 | 1.22 | 14 |
| Increased on-site H&S measures | 3.96 | 1.04 | 15 |
| Inadequate training in COVID-19 protocols | 3.87 | 0.94 | 16 |
| Shortage of labour | 3.96 | 1.04 | 17 |
| Restrictive working conditions | 3.98 | 1.03 | 18 |
| The poor motivation of workers | 3.82 | 1.07 | 19 |
| Reduced number of on-site workers | 3.80 | 1.18 | 20 |
| Delayed certification visits and inspections | 3.94 | 1.07 | 21 |
| Inadequate adoption and use of technology | 3.91 | 1.08 | 22 |
| Inadequate materials procurement planning | 3.76 | 1.19 | 23 |
| Labour inefficiency | 3.75 | 0.99 | 24 |
| Worker absenteeism | 3.73 | 1.15 | 25 |
| Poor transfer of design information | 3.67 | 1.23 | 26 |
| Inadequate site welfare provisions | 3.67 | 1.09 | 27 |
| Inability to provide adequate access to sites | 3.62 | 1.16 | 28 |
| Inadequate H&S provisions | 3.58 | 0.98 | 29 |
| Supervisory incompetence in COVID-19 protocols | 3.56 | 1.20 | 30 |
| Inadequate site layout planning relative to COVID-19 requirements | 3.53 | 1.22 | 31 |
| Poor project management practice | 3.42 | 1.21 | 32 |
| Poor coordination of project team and activities | 3.38 | 1.30 | 33 |
| Poor communication | 3.28 | 1.08 | 34 |
| Inadequate use of plant and equipment | 3.25 | 1.21 | 35 |
| COVID- 19 induced design changes | 3.11 | 1.33 | 36 |
| **Composite MS** | **3.88** | **0.63** | |

Notes: MS = Mean Score, SD = Standard deviation.

Table 3 shows that the mean scores (MSs) for all the factors are greater than the midpoint score of 3.00, which suggest that respondents deem all the factors to have a major as opposed to a minor effect on labour productivity. A composite mean score (MS) of 3.88 indicates that the respondents deem the factors to have a moderate to a near major / near major contribution to reduced construction labour productivity.

The factors ranked 1st to 6th have MSs > 4.20 ≤ 5.00, which suggests that respondents deem these factors to affect construction labour productivity between a near major to a major/major extent. The variables in this cluster include disruptions in the global supply of materials, shortage of materials supply in the domestic market, inadequacies of public transport systems, travel restrictions limiting personnel availability, delays in the delivery of materials, and delays in issuing permits. These results highlight those disruptions in the supply of construction resources, such as materials and labour, had a major effect on labour productivity during the COVID-19 pandemic. The global shutdown of manufacturing and the closure of international boundaries affected the supply of materials from international sources. At a local level, restrictions on local travel, the nationalization of the public transport system and a shutdown of economic activities affected the smooth movement of labour to construction sites and the supply of materials from local firms. The results highlight the risk of over-dependence on global markets for the supply of materials. The results reinforce the findings of Rubin (2020) and Alsharef et al. (2021), which show that late delivery and non-availability of materials reduced labour productivity.

The factors ranked 7th to 32nd have MSs > 3.40 ≤ 4.20, suggesting that respondents deem the factors to have a moderate to a near major / near major effect on construction labour productivity. The top five factors in this cluster are changes in regulations (e.g., introduction of curfews), late payment of salaries and wages, complying with COVID-19 mitigation measures/protocols (such as health screening, cleaning and disinfecting, job-site access and administration), reduced working hours, and low remuneration. The results confirm past studies that job-site COVID-19 mitigation measures affected labour productivity (McLin et al., 2020).

The factors ranked 33rd to 36th have MSs > 2.60 ≤ 3.40, which shows that respondents deem that poor coordination of project team, poor communication, inadequate use of plant and equipment, and COVID-19-induced design changes affect construction labour productivity between a minor to a moderate/moderate extent. However, these factors are ranked low, their MSs > 3.00, which suggests that they have significant ramifications on labour productivity and construction stakeholders should consider them when developing interventions to improve productivity. Notably, some of the factors identified during this study were also identified during pre-pandemic studies suggesting that the COVID-19 pandemic aggravated an existing problem in the sector.

### 4.4 Factor analysis

According to Yong and Pearce (2013), factor analysis is used to analyse the relationship between the original variables and group them into a limited, simple, and interpretable cluster of factors/components. Before conducting factor analysis, Bartlett's Test of Sphericity and the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy were computed to evaluate the appropriateness of the data for factor analysis. Table 4 shows that the KMO coefficient is 0.714, and Bartlett's Test of Sphericity is significant $p = 0.000$ ($< 0.05$) (Hair *et al.*, 2010), suggesting that the data is suitable for factor analysis.

**Table 4**: KMO and Bartlett's Test

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | 0.714 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 1387.866 |
| | df | 595 |
| | Sig. | 0.000 |

Principal component analysis and varimax rotation were applied to extract the COVID-19-related factors affecting construction labour productivity. Six (6) variables were dropped because their factor loadings were less than 0.50 (Hair et al., 2010). The variables dropped are disruptions of the global supply of materials, changes in regulations (e.g., the introduction of curfews), inadequate on-site H&S measures, inability to provide adequate access to sites, and inadequate site layout planning relative to COVID-19 requirements, and inadequate site welfare provisions.

Table 5 shows that nine (9) constructs/components/factors were extracted. The factors with Eigenvalues greater than 1, explained 76.0% of the total variance.

**Table 5:** Results of factor analysis

| **Factor** | **Component** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| *Factor 1: Poor project planning and management* | | | | | | | | | |
| Poor communication | 0.834 | | | | | | | | |
| Poor coordination of project team and activities | 0.818 | | | | | | | | |
| Supervisory incompetence in COVID-19 protocols | 0.816 | | | | | | | | |
| Poor project management practice | 0.805 | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Inadequate materials procurement planning | 0.670 | | | | | | | | |
| Reduced number of on-site workers | 0.576 | | | | | | | | |
| Inadequate H&S provisions | 0.506 | | | | | | | | |
| *Factor 2: Permits and inspection delays* | | | | | | | | | |
| Delays in inspections and certification | | 0.763 | | | | | | | |
| Delays in issuing permits | | 0.733 | | | | | | | |
| Restrictive working conditions | | 0.636 | | | | | | | |
| Inadequacies of public transport systems | | 0.573 | | | | | | | |
| *Factor 3: Cash flow and payment challenges* | | | | | | | | | |
| Low remuneration | | | 0.771 | | | | | | |
| Late payment of salaries and wages | | | 0.765 | | | | | | |
| The poor motivation of workers | | | 0.696 | | | | | | |
| *Factor 4: Compliance with COVID-19 protocols* | | | | | | | | | |
| Complying with COVID-19 protocols | | | | 0.698 | | | | | |
| Worker absenteeism | | | | 0.673 | | | | | |
| Inadequate use of plant and equipment | | | | 0.559 | | | | | |
| Disruptions of the global supply of equipment | | | | 0.510 | | | | | |
| *Factor 5: Project disruptions* | | | | | | | | | |
| Temporary project suspension | | | | | 0.837 | | | | |
| Work stoppages/disruptions | | | | | 0.879 | | | | |
| *Factor 6: Lack of human resources capacity building* | | | | | | | | | |
| Inadequate training in COVID-19 protocols | | | | | | 0.810 | | | |
| Labour inefficiency | | | | | | 0.715 | | | |
| *Factor 7: Material supply disruptions* | | | | | | | | | |
| Shortage of material supply in the domestic market | | | | | | | 0.876 | | |
| Delays in the delivery of materials | | | | | | | 0.827 | | |
| *Factor 8: Labour supply disruptions* | | | | | | | | | |
| Travel restrictions limiting personnel availability | | | | | | | | 0.646 | |
| Reduced working hours | | | | | | | | 0.546 | |
| Labour shortages | | | | | | | | 0.599 | |
| *Factor 9: Design changes and poor transfer of information* | | | | | | | | | |
| COVID-19-induced design changes | | | | | | | | | 0.720 |
| Poor transfer of design information | | | | | | | | | 0.569 |
| Inadequate adoption and use of technology | | | | | | | | | 0.507 |
| | | | | | | | | | |
| Eigenvalues | 12.3 | 2.8 | 2.3 | 1.9 | 1.9 | 1.7 | 1.4 | 1.3 | 1.2 |
| Variance | 35.1 | 8.0 | 6.7 | 5.3 | 5.3 | 4.7 | 4.0 | 3.6 | 3.3 |
| Cumulative Variance | 35.1 | 43.1 | 49.8 | 55.1 | 60.4 | 65.1 | 69.1 | 72.7 | 76.0 |

The extracted factors were named based on the composition of the variables that correlate highly with that factor.

*Factor 1: Poor project planning and management*

The 1st factor was named *'poor project planning and management* and explained 35.1% of the total variance. Seven variables loaded to this factor: poor communication, poor coordination of project team and activities, supervisory incompetence in COVID-19 protocols, poor project management practice, inadequate materials procurement planning, reduced availability of on-site workers due, and inadequate H&S provisions. The COVID-19 pandemic and response efforts put to the test project managers' competencies regarding the ability to adapt and respond to situations effectively. The transition to virtual project leadership and management had several ramifications regarding efficient planning, effective management of the project teams from a much greater distance than usual, and planning to ensure resources are available on-site as and when needed. COVID-19 response efforts such as work-from-home (WFH) arrangements heightened the need for effective communication, new methods of supervision and coordination of teams (at work, home and on-site) and planning regarding procurement to ensure uninterrupted production because of changes in work arrangements. With the imminent risk of COVID-19 infection, inadequate H&S provisions affect workers' ability to work effectively on-site. The research findings are consistent with Rubin (2020) that poor and inefficient planning worsened productivity challenges in the construction sector during the pandemic. The results reaffirm the observations by Jallow et al. (2020) that the COVID-19 pandemic and response efforts make managing projects difficult as staff work from home.

*Factor 2: Delays in inspection and issuing of permits*

The 2nd factor was named *'delays in inspection and issuing of permits'* and explained 8.0% of the total variance. Four variables loaded to this factor: delays in inspection and certification of works, delays in issuing permits, restrictive working conditions, and inadequacies of public transport systems to timely and safely get workers to construction sites. During the COVID-19 Alert Levels 4 and 5, most local authorities' offices were either closed or operated with a skeleton staff, adversely affecting the turnaround time regarding project inspections, work certification, and permit issuing. The results are consistent with broader literature. For example, in the USA, Alsharef *et al.* (2021) report that delays in inspection and issuing permits during the COVID-19 pandemic contributed to a fall in productivity.

*Factor 3: Cash flow and payment challenges*

The 3rd factor was named *'cash flow and payment challenges'*, and explained 6.7% of the total variance. The three variables loading to this factor are low remuneration, late payment of salaries and wages, and poor motivation of workers. The COVID-19 pandemic aggravated the cash flow challenges for contractors, resulting in delayed payment of salaries and low salaries, consequently reducing worker motivation. This finding is corroborated by previous studies, which show that the pandemic significantly affected the psychology and motivation of construction workers (Nguyen *et al.*, 2021), consequently affecting labour productivity. However, as highlighted by Kapsos (2021), labour productivity growth is generally associated with higher wages and better working conditions.

*Factor 4: Compliance with COVID-19 H&S protocols*

The 4th factor was named *'compliance with COVID-19 H&S protocols'* and explained 5.32% of the total variance. The four (4) variables that load to this factor are complying with COVID-19 mitigation measures, increased worker absenteeism (related to COVID-19), inadequate use of plant and equipment, and disruptions of the global supply of equipment. While the intervention to limit workers' exposure to the risk of infection is essential, measures such as social distancing requirements, temperature screening and restrictions on the number of workers required on site are perceived to adversely affect construction labour productivity (Agyekum et al., 2021; Alsharef et al., 2021; King et al., 2021; McLin et al., 2020; Rubin, 2020). A reduction in the number of site workers coupled with limited capital deepening adversely affects labour productivity. Access to machinery and tools is essential to increase labour productivity. Nonetheless, the results are inconsistent with Ohrnberger et al. (2021), who report that compliance with COVID-19 regulations reduces the risk of sickness and morbidity among workers and cumulatively increases productivity. This factor highlights the importance of balancing production and H&S on construction projects and the need for enhanced capital deepening.

*Factor 5: Disruption of project activities*

The 5th factor explained 5.28% of the total variance and was named *'disruption of project activities'*. The two variables that are loaded to this factor are temporary project suspension and work stoppages/disruptions. The factor highlights that the COVID-19 pandemic and response efforts affected labour productivity through work stoppages, project suspensions, and labour travel restrictions. For example, during lockdown Alert Levels 4 and 5, non-essential construction was suspended/stopped, and workers were not actively engaged in construction works. This was confirmed during another study in Zimbabwe, where Chigara and Moyo (2021b) reported that COVID-19 contributed to suspensions and stoppages of construction projects considered non-essential.

*Factor 6: Lack of human resources capacity building*

The 6th factor was named *'lack of human resources capacity building'* and explained 4.73% of the total variance. The two variables that loaded to this factor are inadequate training in COVID-19 protocols and labour inefficiency. The COVID-19 pandemic introduced radical shifts in work organization, which calls for training and retraining of workers to adapt and work effectively in the new environment. However, lack of training meant that workers were not empowered to recognize and avoid work-related hazards and work safely and efficiently, conforming to the pandemic protocols. The results reaffirm the findings of Quezon and Ibanez (2021) that workers' lack of training significantly contributed to low labour productivity in the Philippines during the COVID-19 pandemic. Furthermore, the results reiterate the importance of project-based training to empower workers to work safely and productively during and after the pandemic. Training workers to work safely and productively is essential to increase productivity.

*Factor 7: Material supply disruptions*

The 7th factor was named *'material supply disruptions'* and explained 3.97% of the total variance. Two variables loaded to this factor, namely, shortage of material in the domestic market and delays in the delivery of materials on site. The supply of materials for a construction project is vital to reduce idle time among workers. However, pandemic response interventions such as national lockdowns affected the production of materials and contributed to delays in the supply of materials to construction sites. Glitches in global supply chains aggravated this problem due to a global lockdown and reduced production capacity. This factor confirms extant literature regarding how material supply challenges affected labour productivity during the pandemic. Previous studies show that a reduction in labour productivity during the pandemic was associated with material supply disruption (Rubin, 2020), late deliveries of materials, and shortage of materials (Alsharef *et al.*, 2021; Construction Manager, 2020; King *et al.*, 2021).

*Factor 8: Labour supply disruptions*

The 8th factor was named '*labour supply disruptions*' and explained 3.60% of the total variance. Three variables loaded to this factor, namely travel restrictions limiting personnel availability, reduced working hours, and labour shortages. The COVID-19-related restrictions on the intra-region movement of workers and quarantines affected the ability of workers to travel to construction sites, thereby affecting the availability of critical/skilled labour on site. COVID-19 infections amplified the situation among construction workers, which affected their presence on site. In addition to the limited number of workers permitted on site in line with COVID-19 social distancing requirements, construction labour productivity was affected by the reduction of working hours. During past studies, labour disruptions (Rubin, 2020) and labour shortages (King et al., 2021) were identified as factors contributing to a reduction in productivity in UK and Malaysia, respectively. Borland and Charlton (2020) report a dramatic fall in monthly hours worked from March to June 2020. The COVID-19 pandemic exacerbated labour supply challenges in the construction sector and heightened the call for workforce planning to ensure the successful delivery of construction projects.

*Factor 9: Design change and poor transfer of information*

The 9th factor was named '*design change and poor transfer of information*' and explained 3.29% of the total variance. Three variables loaded to this factor: COVID-19-induced design changes, poor transfer of design information, and inadequate technology adoption and use. The changes in design affect labour productivity through disruptions of workflow and changes in manpower levels in response to the changes. Remote working affected the flow of design change information, with a concomitant effect on on-site activities. The introduction of new work arrangements, such as work from home, highlights the need to embrace various forms of technologies to ensure the real-time transfer of design information from any location. However, the inadequate use of technology to disseminate information during the pandemic was a challenge to construction labour productivity. The results corroborate past studies where poor transfer of design information while remote working was reported to hinder labour productivity in the UK (Rubin, 2020) and Malaysia (King et al., 2021). In another study, Pamidimukkala and Kermanshachi (2021) concluded that workers working from home faced significant challenges due to employers failing to provide them with adequate access to digital infrastructure, resulting in inefficiency and failure to meet project deadlines.

## 5. CONCLUSIONS AND RECOMMENDATIONS

The study investigated the COVID-19-related factors affecting construction labour productivity based on perceptions of construction professionals in Zimbabwe. The top five factors are disruptions of the global supply of materials, shortage of material supply on the domestic market, inadequacies of public transport systems to timely get workers to construction sites, travel restrictions limiting personnel availability, and delays in the delivery of materials on site. Exploratory factor analysis revealed nine (9) significant factors affecting construction labour productivity, namely poor project planning and management, delays in inspection and issuing of permits, cash flow and payment challenges, compliance with COVID-19 H&S protocols, disruption of project activities, lack of human resources capacity building, material supply disruptions, labour supply disruptions, and design change and poor transfer of design information. Given that some factors in this study resonate with those identified during pre-pandemic studies, the results suggest that the factors affecting labour productivity are perennial in construction, hence the need to address them. Furthermore, the results suggest that the COVID-19 pandemic aggravated a systemic problem in the construction industry, thereby highlighting the need for a holistic approach to addressing the productivity challenge in construction.

The results have some important implications for policy and practice. First, the results highlight the importance of capacity building for local building material manufacturing firms to ensure self-reliance regarding the supply of construction materials. Second, poor project planning and management and deficiency in capacity call for collaboration between higher education institutions and industry to develop tailored training programmes to enhance project management skills for project and construction managers and capacitate workers' ability to recognize and respond to hazards while not compromising productivity. However, the main limitation of the study arises from its failure to capture the perspectives of other important stakeholders, such as workers and clients. Future studies should seek to capture the views of these stakeholders to ensure a holistic view of the phenomenon under investigation.

## REFERENCES


Adebowale, O.J. and Agumba, J.N. (2020). A scientometric analysis and review of construction productivity research. International Journal of Productivity and Performance Management, Forthcoming.

Agyekum, K., Kukah, A.S. and Amudjie, J. (2021). The impact of COVID-19 pandemic on the construction industry in Ghana: the case of some selected firms. Journal of Engineering, Design and Technology. DOI 10.1108/JEDT-11-2020-0476.

Akintoye, A. and Fitzgerald, E. (2000). A survey of current cost estimating practices in the UK. Construction Management and Economics, 18, 161-172.

Allan-Blittz, L., Turner, I., Hertlein, F. and Klausner, J.D. (2020). High frequency and prevalence of community-based asymptomatic SARS-CoV-2. MedRxiv. DOI: 10.1101/2020.12.09.20246249.

Alsharef, A., Banerjee, S., Uddin, S.M.J., Albert, A. and Jaselskis, E. (2021). Early impact of the COVID-19 pandemic on the United States construction industry. International Journal of Environmental Research and Public Health, 18(1559), 1-20. https://doi.org/10.3390/ijerph18041559

American Industrial Hygiene Association (AIHA) (2020). Focus on construction health: Covid-19 Guidance document. AIHA, Version 1, August 12, 2020.

Amoah, C., Bamfo-Agyei, E. and Simpeh, F. (2021). The COVID-19 pandemic: the woes of small construction firms in Ghana. Smart and Sustainable Built Environment, (Forthcoming). DOI: https://doi.org/10.1108/SASBE-02-2021-0025.

Bloom, N., Bunn, P., Mizen, P., Smietanka, P. and Thwaites, G. (2020). The impact of COVID-19 on productivity. NBER Working Paper Series. Working Paper 28233. National Bureau of Economic Research, Cambridge.

Borland, J. and Charlton, A. (2020). The Australian labour market and the early impact of COVID-19: An assessment. Australian Labour Market, 53(3), 297-324. https://doi.org/10.1111/1467-8462.12386.

Basu, K.A. (2020). The impact of COVID-19 pandemic on Jordanian civil engineers and construction industry. International Journal of Engineering Research and Technology, 13(5), 828-830.

Chigara, B. and Moyo, T. (2014). Factors affecting labor productivity on building projects in Zimbabwe. International Journal of Architecture, Engineering and Construction, 3(2), 57-65.

Chigara, B. and Moyo, T. (2021a). Factors affecting the delivery of optimum health and safety on construction projects during COVID-19 pandemic in Zimbabwe. Journal of Engineering, Design and Technology, (Forthcoming).

Chigara, B. and Moyo, T. (2021b). Impact of COVID-19 on the construction sector in Zimbabwe. Journal of Construction in Developing Countries, [Forthcoming]. https://doi.org/10.1108/JEDT-02-2021-0096

Creswell, J.W. and Creswell, J.D. (2018). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 5th Ed. Sage, Los Angeles.

Doloi, H., Sawhney, A., Iyer, K.C. and Rentala, S. (2012). Analyzing factors affecting delays in Indian construction projects. International Journal of Project Management, Vo. 30, pp.479-489.

Dozzi, S.P. and AbouRizk, S.M. (1993). Productivity in construction. National Research Council, Canada.

Enshassi, A., Mohamed, S., Mustafa, Z.A. and Mayer, P.E. (2007). Factors affecting labour productivity in building projects in the Gaza strip. Journal of Civil Engineering and Management, 13(4), 245-254. DOI: 10.1080/13923730.2007.9636444.

Feil, X. and Khan, F.H. (2015), Identifying attributes for expert construction project managers in the context of China. International Journal of Asian Social Science, 5(7), 407-418.

Gliem, J.A. and Gliem, R.R. (2003). Calculating, interpreting, and reporting Cronbach's alpha coefficient for Likert-type scales. Paper presented at the Midwest Research-to-Practice Conference in Adult, Continuing and Community Education. The OHIO State University, Columbus, OH, October 8-10, 2003.

Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E. (2010). Multivariate data analysis. 7th ed. Pearson Prentice Hall, New York.
Hamza, H., Shahid, S., Hainin, M.R.B. and Nashwan, M.S. (2019). Construction labour productivity: review of factors identified. International Journal of Construction Management. DOI: https://doi.org/10.1080/15623599.2019.1627503.
Ikediashi, D.I., Ogunlana, S.O., and Boateng, P. (2012). Analysis of risks associated with facilities management outsourcing: A multivariate approach. Journal of Facilities Management, 10(4), 301-316. https://doi.org/10.1108/14725961211265756
International Labour Organisation (ILO) (2020). In the face of a pandemic: ensuring safety and health at work, ILO, Geneva.
Jallow, H., Renukappa, S. and Suresh, S. (2020). The impact of COVID-19 outbreak on United Kingdom infrastructure sector. Smart and Sustainable Built Environment, doi - 10.1108/SASBE-05-2020-0068
John Hopkins University (JHU) (2021). COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at JHU, available at: https://coronavirus.jhu.edu/map.html (accessed 20 December 2021).
Kapsos, S (2021). Why would labour productivity surge during a pandemic?, ILO, Geneva. Available at: https://ilostat.ilo.org/why-would-labour-productivity-surge-during-a-pandemic/ [accessed 02.01.2022]
King, S., Rahman, R.A., Fauzi, M.A. and Haron, A.T. (2021). Critical analysis of pandemic impact on AEC organizations: the COVID-19 case. Journal of Engineering, Design and Technology, DOI 10.1108/JEDT-04-2021-0225.
Losby, J. and Wetmore, A. (2012). CDC Coffee break: Using Likert scales in evaluation survey work. National Centre for Chronic Disease Prevention and Health Production.
McLin, M., Doyon, D., Lightner, B., Federle, M. (2020). Pandemics and construction productivity: Quantifying the impact. Washington: Maxim Consulting Group and Marquette University.
Ministry of Health and Child Care (2021). COVID-19 daily updates, 20 December 2021, Ministry of Health and Child Care, Harare.
Nguyen, V.T., Nguyen, B.N., Nguyen, T.Q., Chu, A.T. and Dinh, H.T. (2021). The impact of COVID-19 on the construction industry in Vietnam. International Journal of the Built Environment and Sustainability, 8(3), 47-61.
O'Leary, Z. (2017). The Essential Guide of Doing Your Research Project, 3rd ed, Sage, Los Angeles.
Pamidimukkala, A. and Kermanshachi, S. (2021). Impact of COVID-19 on field and office workforce in construction industry. Project Leadership and Society, 2(2021)1000018, 1-10.
Pasco, R., Du, Z., Wang, X., Petty, M., Fox, S.J. and Meyers, L.A. (2020). COVID-19 in Austin, Texas: Epidemiological assessment of construction work. UT COVID-19 Consortium, 5 April 2020. Available online: https://cid.utexas.edu/sites/default/files/cid/files/covid-19 (accessed 21 March 2021).
Quezon, E.T. and Ibanez, A.G. (2021). Effect of COVID-19 pandemic in construction labour productivity: A quantitative and qualitative data analysis. American Journal of Civil Engineering and Architecture, 9(1), 23-33. DOI:10.12691/ajcea-9-1-4.
Raoufil, M. and Fayek, A.R. (2021). Identifying actions to control and mitigate the effects of the COVID-19 pandemic on construction organizations: Preliminary findings. Public Works Management and Policy, 26(1), 47-55.
Rubin, D.K. (2020). Analysis: COVID-19 causes 35% productivity loss at UK projects. Engineering News-Record, Available online:
The Construction Manager (2020, 23 June). COVID-19 causing extra 15% productivity loss on UK sites. Available online: https://constructionmanagermagazine.com/covid-19-causing-extra-15-productivity-loss-on-uk-sites/ [Accessed 20 October 2020]
van Biesebroeck, J. (2015). How tight is the link between wages and productivity? A survey of the literature. Conditions of Work and Employment Series No. 54. ILO, Geneva.
Walker, A. (2015). Project Management in construction. West Sussex: Wiley Blackwell.
Workplace Health and Safety Queensland (2020). PN12613 – Work health and safety during COVID-19 – Guide to keeping your workplace safe, clean and healthy. Version 2, 9 June 2020. The State of Queensland.

World Health Organisation (WHO) (2020). Advice on the use of masks in the context of COVID-19 – Interim guidance. 5 June 2020. Available at: https://apps.who.int/iris/handle/10665/331693 [Accessed 15 December 2021]
Yong, A.G. and Pearce, S. (2013). A beginner's guide to factor analysis: focusing on exploratory analysis. Tutorials for Quantitative Methods for Psychology, 9(2), 79-94.
Zimbabwe National Statistics Agency (ZimStat) (2019). Understanding Gender Equality in Zimbabwe: Women and Men in Zimbabwe Report 2019, ZimStat, Harare.

Journal of Construction Project Management and Innovation, 12(1): 34-54, 2022
ISSN 2223-7852


# The use of digital project management solutions by project businesses: a case study of a selected platinum mine in the Limpopo province

**Kgothatso Erens Mahlo[1] and John Peter Spencer[2]**

[1&2]Graduate Centre of Management, Faculty of Business and Management Sciences, Cape Peninsula University of Technology, Cape Town, South Africa

Email: kgothatsoerens@gmail.com; jpsafron@mweb.co.za

## ABSTRACT

There have been specific technological shifts globally in the discipline of project management, which include the implementation of Project Management Software (PMS) packages. PMS is a pliant software solution that is used for managing projects: administrating, planning, organising, resources managing, document managing, costs, and time management. The awareness and adoption of PMS is unclear, especially in developing countries. This study has examined the awareness and adoption levels of digital project management solutions by project businesses at a selected opencast platinum mine in the Limpopo Province. The study also investigated project management challenges, and the impediments of adoption and the readiness of project businesses to adopt digital project management solutions. A quantitative research survey was distributed and emailed to project businesses at mine, where 110 project businesspersons participated in this study. SPSS v26.0 software was utilised to process data. The study publicised that the level of awareness of digital project management tools is higher than the level of adoption. Several barriers were identified as the impediments of adopting digital project management tools. It is recommended in the study that PMS developers should consider integrating with other systems that could enhance project management processes. It is also recommended that they should consider creating different packages for all business sizes and project magnitudes.

**Keywords:** Digital project management tools, project business, Project Management Software (PMS), project management

## 1. INTRODUCTION

The national economy and employment levels of South Africa has been uplifted by mining businesses from 1900. The mining sector elevated business growth and employment through offering business opportunities to project-based organisations in their neighbouring communities. The organisations are faced with numerous project management challenges despite their different magnitudes. Kuvshinkov et al. (2017:1) highlighted those four out of five projects in the mining sector exceeded their set timeframes and budgets on an average of 43%. This has persuaded software developers to implement digital project management tools that can restrain project management challenges, where the purpose of these tools is to simplify project management activities through automated systems. Advances in project management systems were established in the past 29 years, even though their adoption and acceptance levels are indefinite (Arnold and Javernick-Will, 2013:511). However, it is crucial to understand the substantial awareness, adoption, and practical influence of digital project management tools, particularly in developing countries such as South Africa. Studies by Sajad et al. (2016:39), Puška et al. (2020:90) as well as Hassan and Asghar (2021:26840) have noted that digital project management tools have hardly simplified project activities and business processes, but instead have been the cause of failure for some projects. This failure is claimed to have been caused by project overruns, over-charges, and customer dissatisfaction arising from the failure to match customer expectations.

There is an exigency for further research in the discipline of project management, therefore, this study focuses on investigating the levels of awareness, adoption, and acceptance of digital project management tools in the South African mining sector. The aim of the study is to investigate the challenges associated with various projects, as well as the awareness and adoption levels of digital project management solutions amongst project businesses at the selected mine in the Limpopo province, to achieve an understanding of how digital project management solutions can contribute to the growth, administration, and management of project businesses.

## 2. OVERVIEW OF PROJECT MANAGEMENT TECHNOLOGY

Project management technology is a model of technological tools that are used for managing projects (Puška et al., 2020:90). Project management technology involves the deployment of high-tech systems and networks that are utilised for storing and handling project management data (Arnold and Javernick-Will, 2013:510). The use of project management technology has become beneficial in simplifying the planning and communication sections of projects. Gustavsson et al. (2012:527) point out that most project businesses that have invested in technology-tools have barely achieved their anticipated goals and, as such, it is suggested that upon the adoption of technology- tools, business processes should be amended and all project actors should partake in the utilisation of such tools (Gustavsson et al., 2012:522; McGrath and Kostalova, 2020:1).

According to Gustavsson et al. (2012:525) architects are professionals that often utilise technology-tools than any other experts, such as project managers and engineers. The author proceeded to report that the delay in using advanced project digital tools is caused by the lack of mobile devices and the unfamiliarity of digital tools. The reluctance of contractor site managers to adopt digital project management tools is also seen as a barrier as only 40% of contractors in 2012 are reported to be using digital tools in the initiation phase of their projects, only to manage critical factors such as time and resource planning (Gustavsson et al., 2012:525). Nevertheless, this figure is slowly shifting as Klynveld Peat Marwick Goerdeler (KPMG) et al. (2019:8) and Wellingtone (2020:11) have observed differences in the use of technology-tools by contractors. In this regard, McGrath and Kostalova (2020:3) projected that more contractors are likely to introduce Information Technology (IT) tools for their future projects.

Adriaanse et al. (2010:74) declare that the use of technology in organisations could be obligatory or voluntary, depending on the conditions of the industry; some projects have short-term durations that limit the period of initiating and introducing technical tools in their organisations. Son et al. (2012:83) contend that some project site-managers are reluctant to use technology when their commercial contracts contain restrictions regarding the utilisation of technology in managing projects.

### 2.1 Project management software (PMS)

PMS is the "collection of electronic instruments that enhance the efficiency, planning and tracking of deliverables for a project team" (Bedneko, 2019:1). PMS is a "flexible cloud-based project solutions that ease the project workflow, collaboration and filing" (Kashyap, 2018:1).

The purpose of PMS is to ease business processes in the lifecycle phases of project management (Puška et al., 2020:90).

Project managers in recent times are assisted by many project-management technical apparatuses and practices. The commercial field has noted that stakeholders have become accustomed to requesting quality projects that could be delivered in a short timeframe. Therefore, this has positioned a necessity for further improvements in the field of computer technology (Hajjaji et al., 2010:125). There are some software packages, which are commonly used in project management, such as Microsoft Excel and Microsoft Project, which are applied to analyse risks and construct project management models. Other PMS tools that are commonly used include the Palisade Software and PRISM, which are products of the Palisade Corporation founded in 1984. These tools can be utilised to analyse project risks by generating important statistical techniques such as Monte Carlo simulations, which is a statistical method applied by project managers to gain an in-depth understanding of the effects that risks and improbabilities can have in project management (Al Shaer, 2018:1). The Palisade Corporation is reputable for providing leading project risk analysis software packages. For example, the company established the @Risk package, which has graphical features incorporated with Monte Carlo simulation in MSE (Palisade, 2010:1).

According to Borštnar and Andreja (2014:19), top managers, project managers and the project team workers at large are backed by technological programs in every project. The authors highlight that IT serves as a communication platform between the organisational structures of project businesses and, as such, every department utilises PMS tools for different functions. Top management uses PMS packages for tracking financial pointers and key performance indicators (KPIs), while project managers use PMS packages for project planning and reporting. The project team members utilise PMS packages for administration and communication purposes. Studies, such as those of Raymond and Bergeron (2007:219) and Pellerin et al. (2013:864), indicate that low-performing projects are those that have low usage of software packages. These studies further state that every project performance is linked to multiple software subsystems. These software subsystems cannot be compromised as they include functions of documentation control, project definition, construction activity administration and cost management.

### 2.2 Project management technology's influence on growth and success

There is a direct connection between the use of technological tools and the growth of many organisations. Several experienced organisations that are at a high maturity level, are more likely to employ project management technical implements and systems, while 95% of project businesses at the high maturity level utilise project management technical implements and systems, opposed to 55% at a low level of maturity (PWC, 2012:18). According to a survey conducted by Wellingtone (2020:9), many organisations are progressively becoming dissatisfied with their level of project management maturity. This was concluded after 45% of project businesses in 2016 were unhappy about their level of maturity and in 2020 this had increased to 52%. Furthermore, only 35% of project businesses are satisfied with their level of project management maturity. The Wellingtone (2020:9) survey further highlighted project management tools and technology as critical factors in the project management maturity radar. In addition to the above, the KPMG et al. (2019:15) survey reflects that project businesses should invest in new technology for enhanced collaboration implements and artificial intelligence tools to allow quick and effective utilisation of project management information that will aid decision-making. The adoption of collaborative technological tools (which can be used jointly) is relevant because it was revealed that 51% of project businesses utilise these tools to ensure the delivery of their projects, even although the effectiveness and efficiency of such tools have not been determined (KPMG et al., 2019:11-12). In addition, it was noted that only 8% of project businesses globally have introduced artificial intelligence tools into their organisations to support their projects, but the percentage is expected to increase (KPMG et al., 2019:11-12).

### 2.3 Recognition and adoption of technical project management solutions

Price Waterhouse Coopers (PWC) (2012:18) point out that the adoption of project management technical tools and techniques has become standardised among project businesses, and record that only 77% of project businesses are mindful of technical project management solutions and use such tools in their projects. The trend is supported by KPMG et al. (2019:8) in their global survey of project management, which found that project management technical tools and procedures were widely used by 71% of project businesses worldwide. However, the Wellingtone (2020:11) survey held a different view, which argues that the employment of project management technical tools and techniques is low, since only 25% of project businesses make use of project management technical tools. According to Wellingtone (2018:12; 2020:11), the adoption of project management technical tools has only changed gradually with an increment of 3% between 2018 and 2020. Considering the above, it is comprehensible that the awareness and adoption of project management technical solutions by project businesses is ambiguous and, as such, more research is needed. Since the utilisation of project management technical tools and practices is associated with an organisation's performance, Figure 1 shows the project performance ranks.

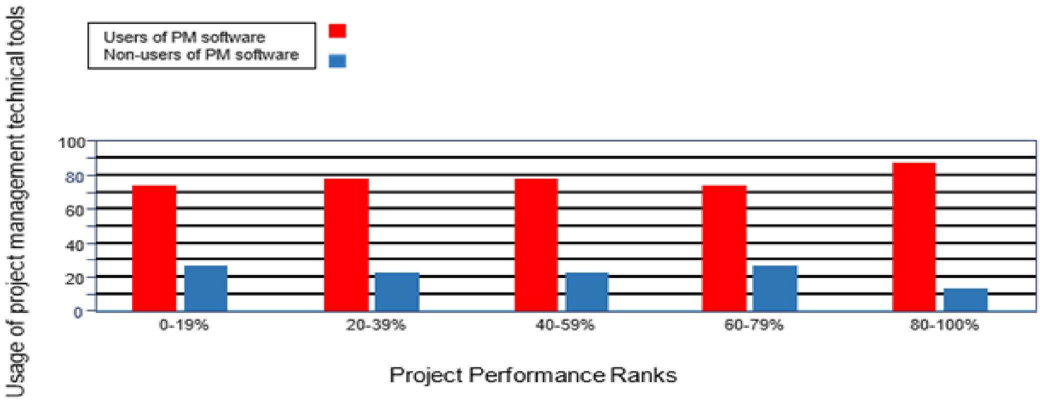


**Figure 1:** The usage of PMS
Source: Adapted from PWC (2012:19)

Figure 1 portrays a link between the use of project management technical tools and the performance of a project. The Figure reveals that project businesses which use digital project management tools have elevated performance levels compared to those that do not use any tools. PWC (2012:18) dissent that there is a solid connection between the usage of project management technical tools and project performance. Among well-performing projects, 87% are carried out by project businesses that apply project management technical tools and techniques (PWC, 2012:18).

Brynjolfsson and Yang (1996:39-40) discovered that the implementation of project management technical tools and practices did not often result in anticipated outcomes. McGrath and Kostalova (2020:8) supported these findings by adding that project management technical tools and practices should be backed-up by a high-performance team and a proficient leader as this would help produce the required results. The unanticipated outcomes of project management technical tools are referred to as the paradox of productivity, which includes inaccurate measures of productivity, long observations that are focused on increasing productivity, poor management of PMS tools, and the inability to anticipate a Return on Investment (ROI) of PMS tools (Dewett and Gareth, 2001:337; Bresnahan et al., 2002:28; Bardhan et al., 2007:589; Aubert and Reich, 2009:32). In the past years, many researchers became interested in investigating the impact of project management technical tools and techniques because of the paradox of productivity in organisations. For example, the study of Bryde and Wright (2007:5) exposed the connection between project management technical tool- efficiency and the project team members' expectations, as well as clients' expectations. Ali et al. (2008:5) investigated the effect of PMIS (Project Management Information System) and discovered that PMIS had a positive effect on project performance, while Raymond and Bergeron (2007:217-219) publicised the recurrent usage of PMIS and its positive impact on project performance. The study of Dostie and Jayaraman (2008:1) indicated a high productivity level of employees that used computers against those that did not, while Pellerin et al. (2013:21-22) highlighted the level of PMS usage and its correlation with project performance of engineering projects in Canada. However, these studies were less focused on ascertaining any correlation between the recognition and employment of project management technical solutions and their challenges on the African continent and, as such, the current study focused on South African project businesses.

## 3. RESEARCH METHODOLOGY

The empirical segment of this study was constructed on a quantitative research design since theories of arguments and models were used to generate data themes and assess philosophies. Data was gathered through surveys and research papers (journals, newspapers, articles, and academic papers). Statistical methods were employed to present the findings of this study, where the focus was to evaluate the statistical levels of adoption, awareness, and challenges of using digital project management solutions and as such, primary data was collected from project businesses.

Wright et al. (2016:97) mentioned that a quantitative study approach starts with an empirical logic that has extensive theories of arguments and models which are used to generate data themes. Quantitative researchers (for example, Elkatawneh, 2016) collect data by utilising various data collection instruments to minimise irrelevant information. This is done to improve the research results and to possess widespread findings regarding the subject of the study. Researchers who employ a quantitative approach collect data through observations and interviews in their field of study, often utilising a survey (Elkatawneh, 2016:2). The dynamics of a quantitative methodology are based on statistical data, which offers convenience in terms of saving time and resources in a research project. In a quantitative study, generalisation is built based on scientific techniques that are utilised to gather data and researchers can focus on various research groups where participants provide their input based on their experiences (Daniel, 2016:94). The main objective of a quantitative study is to reduce the researcher's direct involvement in the information gathered for the study (Wright et al., 2016:98).

The appropriate paradigm for this study was the interpretive paradigm since the researcher aimed to understand how others comprehend events and theories (Lan, 2018:3), and aimed to comprehend subjective meanings of certain social views and interpret the research findings of several continuums with pragmatism being the focal point (Rahl, 2017:1; Cao Thahn and Le Thahn 2015:24). Interpretation in this study is applied to the adoption levels of project management digital solutions and the challenges encountered by project businesses at the selected opencast platinum mine in the Limpopo Province. The research design of this study was constructed on a cross-sectional descriptive case study to examine the challenges and adoption levels of digital project management solutions.

The target population for this study was a restricted number of selected contracting project businesses at the selected platinum mine, and the population of this study comprised:

- Project managers appointed by the contracting projects businesses in line with the prescripts of the Mine Health and Safety Act, 29 of 1996 in the Republic of South Africa.
- Contracting site managers employed in line with the prescripts of the Mine Health and Safety Act, 29 of 1996 of the Republic of South Africa under regulation 2.6.1 of the Act.
- Contracting supervisors employed in line with the prescripts of the Mine Health and Safety Act, 29 of 1996 in the Republic of South Africa under regulation 2.9.2 of the Act.

The project businesses participants were categorised and selected from 313 contracting organisations at a selected platinum mine and based on the Contractor Management System of the selected mine; 180 contracting organisations were identified as project businesses on system reports (that categorised contracting businesses per their scope of work and nature of business). A total of 110 project businesses participated in the study.

The non-probability sampling technique was suitable for this study since a non-random selection technique was employed to select participants. Purposive/judgemental sampling was applied since not all the contracting businesses that were identified met the criteria of the project businesses that are needed to answer the research questions (Etikan et al., 2016:4; Wright et al., 2016:98). Purposive/judgemental sampling was employed to increase the applicability of the sample so that only businesses that met the criteria of the study sample were included (Trochim, 2020:1).

To improve the response rate, data were collected through structured closed-ended questionnaires, which contained questions that had multiple-choice answers for respondents to choose the appropriate answer (Wilkinson and Birmingham, 2003:11). The researcher reviewed the data collection instruments of other related studies in designing the questionnaire for this study, which was distributed between June 2020 and January 2021.

A single questionnaire was utilised for all participants and selected case analysis was utilised to separate the data. The survey questionnaire consisted of four sections:

Section A of the survey included a demographic and general profile about business details, numbers of employees, number of years in business, nature of projects, and type of project business in the demarcated area. Multiple-choice questions were utilised. SPSS v26.0 was used to analyse data for all sections (A to D) using the selected cases function where data was split between group A (project business that have not adopted digital project management tools) and group B (project business that have adopted digital project management tools).

Section B evaluated the project history and project challenges faced by project businesses within the specified mining area. Multiple-choice questions were utilised. The research objective was to examine project management-related challenges of project businesses in the demarcated area.

Section C part 1 evaluated adoption levels of digital project management solutions by project businesses. Multiple choice and dichotomous questions were used. The research objective was to investigate the awareness and adoption levels of technological project management solutions by project businesses in the demarcated area.

Part 2 of Section C accessed the barriers to digital project management solutions by project businesses. A five-point Likert scale was applied. The research objective was to investigate the adoption barriers to digital project management solutions by project businesses in the demarcated area.

Section D evaluated the organisations' readiness and willingness to adopt digital project management solutions in the demarcated area. A five-point Likert scale was applied. The research objective was to determine the level of readiness to explore digital project management technical tools by project businesses in the demarcated area.

The data analysis of Sections A, B and C addressed the last research objective, which was to understand the extent to which project management technology could influence the grow and success of project businesses at the selected mine.

In consideration of the availability and variety of the participants, the researcher either physically distributed or emailed the questionnaire to the project managers, site managers and supervisors of the project businesses at the selected mine.

Table 1: Example of how data was analysed

| **Variable** | **Label on SPSS** | **Label value on SPSS (coding value)** | **Data Analysis** |
|---|---|---|---|
| **Profile of the sample** | | | |
| Gender | Male<br>Female | = 1<br>= 2 | Used SPSS Selected Cases Function (Filtered Group A & B data) |
| Occupation | Project Manager<br>Contracting Site Manager<br>Contracting Supervisor<br>Other | = 1<br>= 2<br>= 3<br>= 4 | Used SPSS Selected Cases Function (Filtered Group A & B data) |
| Number of employees | 1-9<br>10-20<br>21-50<br>51-99<br>Over 100 | = 1<br>= 2<br>= 3<br>= 4<br>= 5 | Used SPSS Selected Cases Function (Filtered Group A & B data) |
| Number of projects | *#Number* | *#Number* | Used SPSS Selected Cases Function (Filtered Group A & B data) |

| | | | | |
|---|---|---|---|---|
| Number of successful projects | *#Number* | *#Number* | | Used SPSS Selected Cases Function (Filtered Group A & B data) |
| **Project related data** | | | | |
| Project management challenges | Selection of options | Not Selected = 0<br>Selected = 1 | | Used SPSS Selected Cases Function (Filtered Group A & B data) |
| **Level of awareness and adoption of digital project management tools** | | | | |
| DQ1 | Awareness of digital project management tools | Yes<br>No | = 1<br>= 2 | Used SPSS Selected Cases Function (Filtered Group A & B data) |
| DQ2 | Use of digital project management tools. | Yes<br>No | = 1<br>= 2 | Used SPSS Selected Cases Function (Filtered Group A & B data) |
| **Most used project management software packages** | | | | |
| Project Management Software Packages | Trello | Not Selected = 0<br>Selected = 1 | | Analysed data for Group B – using the Selected Cases Function on SPSS |
| | BaseCamp | Not Selected = 0<br>Selected = 1 | | |
| | Microsoft Project | Not Selected = 0<br>Selected = 1 | | |
| | Smart Sheet | Not Selected = 0<br>Selected = 1 | | |
| | Huddle | Not Selected = 0<br>Selected = 1 | | |
| | Oracle Primavera | Not Selected = 0<br>Selected = 1 | | |
| **Analysis of the barriers to adopting digital project management solutions** | | | | |
| SWLS1 | Lack of knowledge | Strongly Disagree = SD | = 1 | |
| | | Disagree = D | = 2 | |
| | | Neutral = N | = 3 | |
| | | Agree = A | = 4 | |
| | | Strongly Agree = SA | = 5 | |
| SWLS2 | High costs of adoption | Strongly Disagree = SD | = 1 | |
| | | Disagree = D | = 2 | |
| | | Neutral = N | = 3 | |
| | | | | |
| | | Agree = A | = 4 | Analysed data for Group A – using the Selected Cases Function on SPSS |
| | | Strongly Agree = SA | = 5 | |

Source: Researcher construct

Reliability and validity in this study were achieved by reviewing literature papers, attaining validations from experts, conducting a pilot study, and obtaining approval from the CPUT Research and Ethics Committee of the Faculty of Business and Management Sciences. Internal reliability was measured using the Cronbach's alpha test (α) and the CR test. The researcher was led by the guidelines of the CPUT Research Directorate and Graduate Centre of Postgraduate Management Studies. Coding was applied in the data processing stage. The SPSS v26.0 system was employed to analyse data and a descriptive statistical analysis approach was employed to process data. Tables and graphs were generated to depict frequencies, as well as the relevant arithmetic means and spread measures.

Ethical approval to conduct this study was sought from the CPUT Research and Ethics Committee of the Faculty of Business and Management Sciences. The researcher was led by the guidelines provided by the CPUT Research Directorate and Graduate Centre of Postgraduate Management Studies. The researcher desisted from the fabrication of authorship, evidence, information, data results or conclusions, plagiarism, revealing information that would harm participants, using vague and inappropriate language, sharing data with others, retain data and other materials longer than necessary and replicating publications.

## 4. RESEARCH RESULTS

This section presents the statistical findings of this study. Table 2 includes a report of data collected from the sample.

**Table 2:** Data analysis

| **Series A** | **Series B** | **Group A** | | **Group B** | |
|---|---|---|---|---|---|
| | | **Project businesses that have not adopted digital project management tools** | | **Project businesses that have adopted digital project management tools** | |
| | | **Frequency** | **Percentage** | **Frequency** | **Percentage** |
| **Profile of the sample** | | | | | |
| Gender | Male | 55 | 90.2 | 43 | 87.8 |
| | Female | 6 | 9.8 | 6 | 12.2 |
| Occupations | Project Manager | 5 | 8.2 | 5 | 10.2 |
| | Site Manager | 49 | 80.3 | 35 | 71.4 |
| | Supervisor | 5 | 8.2 | 4 | 8.2 |
| | Other | 2 | 3.3 | 5 | 10.2 |
| Education | Secondary school | 9 | 14.8 | 6 | 12.2 |
| | Technical college | 49 | 80.3 | 16 | 37.2 |
| | First diploma/degree | 3 | 4.9 | 25 | 51 |
| | Master's degree | 0 | 0 | 2 | 4.1 |
| Nature of Business | Engineering | 63 | | 55 | |
| | Construction | 32 | | 37 | |
| | Other | 5 | | 8 | |
| Locality | Mokopane local business | 57 | 66.28 | 29 | 33.72 |
| | Not Mokopane local business | 4 | 16.66 | 20 | 83.33 |
| No. of Employees | 1 to 9 | 40 | 66 | 20 | 41 |
| | 10 to 20 | 15 | 25 | 7 | 14 |
| | 21 or more | 7 | 11 | 22 | 45 |
| No. of years in business | Less than 1 year | 7 | 11 | 0 | 0 |
| | 1-5 years | 33 | 54 | 15 | 31 |
| | 6 year or more | 21 | 34 | 34 | 69 |
| No. of years in the mining sector | Less than 1 year | 6 | 10 | 2 | 4 |
| | 1-5 years | 41 | 67 | 15 | 31 |

| | | | | | |
|---|---|---|---|---|---|
| | 6 year or more | 14 | 23 | 32 | 65 |
| **Project related data** | | | | | |
| Projects | Number of Projects initiated | 1084 | | 1782 | |
| | Successful Projects | 1068 | 98.5 | 1755 | 98.5 |
| | Unsuccessful Projects | 16 | 1.5 | 27 | 1.50 |
| Project Management challenges | Identified | - Lack of resources<br>- Limited budget<br>- Changes in project requirements<br>- Economic changes<br>- Supplier-related issues | | - Poor communication<br>- Economic changes<br>- Supplier-related issues<br>- Unanticipated weather conditions | |

Source: Researcher construct

*Gender* - Most of the participants employed by the project businesses are male for both groups of businesses. The results include n=55, representing 90% for Group A and n=43; representing 87.8% for Group B. Very few participants were female (n=6; representing 9.8% for Group A and n=6; representing 12.2% for Group B). The data suggest that most project businesses within the mining industry employ predominantly male candidates for their senior positions.

*Occupations* - The leading occupations for both groups are contractor site managers (n=49; representing 80.3% and n=35; representing 71.4%). In Group A, the second most dominant occupation is contracting site supervisor (n=5; representing 8.2%) and the project manager (n=5; representing 8.2%). For Group B, the second highest occupation is project manager (n=5; representing 10.2%) and the 'other' occupations (n=5; representing 10.2%). The 'other' occupations for Group B included two safety officers, one construction manager and two Quality Assurance, Environmental, Health and Safety managers. The least dominant occupation for Group A is the 'other' occupations (n=2; representing 3.3%) which consists of one managing director and one safety officer. For Group B, the least dominant occupation is contracting supervisor (n=4, representing 8.2%). From this data, it can be concluded that the key occupation of project manager is not as dominant as anticipated for project businesses that operate in the mining sector.

*Education* - Most respondents in Group A have technical college qualifications (n=49; representing 80.3%), while the highest educational level for Group B is a first degree and/or diploma qualification (n=25; representing 51%). The second highest educational level for Group A is secondary school (n=9; representing 14.8%) and technical college education for Group B (n=16; representing 32.7%). Master's degrees were lacking among participants, with Group A returning 0 and Group B (n=2, representing 4.1%).

*Nature of Business* - Most of the project businesses that participated in this study selected engineering as their nature of business (Group A is represented by 63% and Group B is represented by 55%), followed by construction (Group A at 32% and Group B 37%). The 'other' category represents the lowest values for both groups (Group A at 5% and Group B at 8% selection rate). The 5% for Group A represents mining (1%), pest control (1%) and waste management (2%), while the 8% for Group B represents mining (2%) and information technology (6%).

*Locality* – There are 66.28% (n=57) of Mokopane district project businesses that have not adopted digital project management tools; and 33.72% (n=29) that have adopted digital project management solutions. There is also 83.33% (n=20) of project businesses that are not from the Mokopane district that have adopted digital project solutions; and 16.66% (n=4) that have not adopted digital project management solutions. The results show that the cluster of non-local Mokopane (Waterberg) district project businesses have a high proportion of participants that have adopted digital project management tools. However, there is a high number of Mokopane district project businesses that have not adopted digital project management tools, which suggests that locality does play a role in influencing the adoption of digital project management tools.

*Number of employees* - Most of the project businesses that have not adopted digital project management tools (Group A) have between 1 to 9 employees, representing 66% (n=40), while most of those that have adopted digital project management tools (Group B) have 21 or more employees, representing 45% (n=22). The second highest ranking for Group A is project businesses that have between 10 and 20 employees (representing 25%; n=15), and 1 to 9 employees for Group B (representing 41%; n=7). The lowest ranking for Group A consists of businesses that have 21 or more employees (representing 11%; n=7), and 10 to 20 employees for Group B (representing 14%; n=7). These results were important in indicating the influence of workforce size in adopting digital project management solutions. The results suggest that project businesses with a higher number of employees are more likely to adopt digital project management solutions than those with fewer employees.

*Number years in business* - Most of the project businesses that have not adopted digital project management solutions (Group A) are those that have been in operation for between 1 and 5 years (representing 54%; n=54), while most of the project businesses that have adopted digital project management tools (Group B) are those that have been in operation for 6 or more years (representing 69%, n=34). The second cluster of project businesses that have not adopted digital project management tools (Group A) are those with 6 or more years of business operation (representing 34%; n=21). The second group of project businesses that have adopted digital project management tools (Group B) contains businesses that have been operating for 1 to 5 years (representing 31%; n=15). There are also seven project businesses in Group A with less than one year of business operation, which have not adopted digital project management tools, representing 11%. Group B does not have businesses that have been operating for less than one year.

*Number of years in the mining sector* - Most of the project businesses that have not adopted digital project management solutions (Group A) are those with between 1 and 5 years of business operation in the mining sector (n=41; representing 67%), while most of the project businesses that have adopted digital project management tools (Group B) are those with six or more years of business operation in the mining sector (n=32; representing 65%). The second grouping of project businesses that have not adopted digital project management tools (Group A) are those with six or more years of business operation in the mining sector (n=14; representing 23%). Group B, that have adopted digital project management tools, includes businesses that have been operating in the mining sector for 1 to 5 years (n=15; representing 31%). There are also six project businesses in Group A with less than one year in business operation in the mining sector (representing 10%) and two project businesses for

Group B that have adopted digital project management tools (representing 4%). Group B does not have businesses that have been operating for less than one year. These results suggest that industry experience has an influence on the adoption of digital project management tools in the same way as experience in the mining industry.\

*Projects* - The data shows that Group B project businesses have embarked on far more projects than Group A project businesses. This indicates that project businesses that have more experience and exposure tend to adopt digital project management tools.

The participant project businesses yielded similar results of project success. Project businesses that have adopted digital project management solutions were successful in 98% of their projects, which is like project businesses that have not adopted digital project management tools.

*Project management challenges* - Internal challenges affected project businesses that do not use digital project management tools more than those that do. For example, the 'lack of resources', 'limited budget' and 'changes in project requirements' were internal challenges that affected project businesses that do not use digital project management tools, whereas project businesses that use such tools are only affected by 'poor communication' in their projects. Regarding external challenges, they similarly affected both groups of project businesses. For example, 'economic changes' and 'supplier-related issues' affected both groups of project businesses. The only external challenge that individually affected project businesses that use digital project management tools was 'unanticipated weather patterns', which was prompted by the higher number of outdoor construction projects.

Table 3 shows dichotomous scaling values regarding the awareness and usage of digital project management tools based on project businesses that participated and suggests that 59.1% (n=65) of project businesses were aware of digital project management solutions, whereas 40.9% (n=45) were not aware. Table 3 also shows that 44.5% (n=49) of project businesses use digital project management solutions and 55.5 (n=61) do not use digital project management solutions.

**Table 3:** Level of awareness and adoption of digital project management tools

| Coding | Variables | PM PHASE | Dichotomous scaling | | | |
|---|---|---|---|---|---|---|
| | | | YES | | NO | |
| | | | Percentage | Frequency | Percentage | Frequency |
| **DQ1** | Level of digital PM tools Awareness | Project Initiation | 59.1 | 65 | 40.9 | 45 |
| **DQ2** | Level of digital PM tools usage in Projects | Project Initiation | 44.5 | 49 | 55.5 | 61 |

Source: Research construct

Figure 2 illustrates the awareness levels of digital project management systems. The chart is classified as per the number of business operating years of the project businesses in the mining sector. Figure 2 shows that project businesses that have been operating in the South African mining sector for 16 to 20 years and more have the highest rate of digital project management tools awareness, followed by those with between 6 and 10 years (representing 76.9%), then by those with between 11 and 15 years (representing 66.7%). The project businesses with less than one year and those with 1 and 5 years in operation represent the lowest rates of awareness. The results above suggest that experienced project businesses in the South African mining sector are more aware of digital project management tools than those that are less experienced.

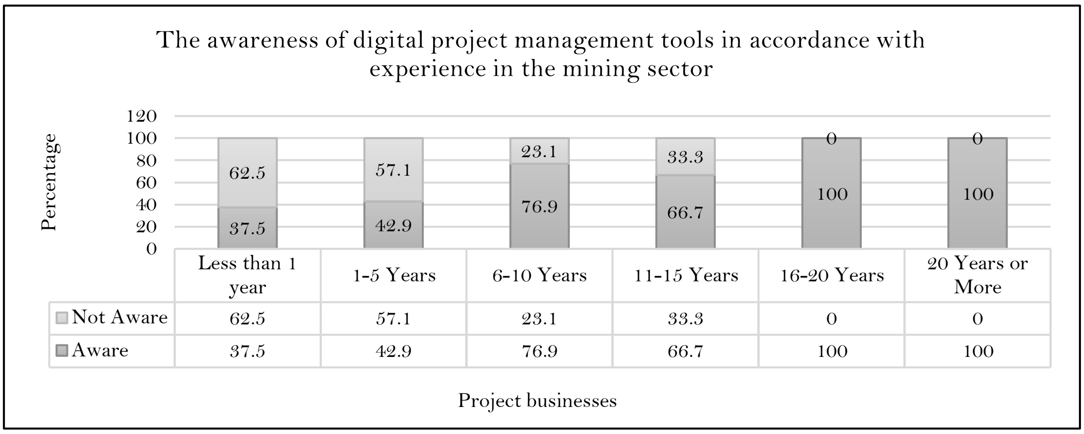


**Figure 2:** Awareness levels of digital project management systems

The information in Table 4 shows the extent of utilisation of digital project management tools, which addresses one of the research aims of this study. It can also be seen that digital project management solutions are utilised for numerous purposes. Considering this data, it can be confirmed that most project businesses use digital project management frequently for planning projects and managing safety and risk (categorised as the 1st class of usage). Digital project management solutions are also used for scheduling, time-tracking, and managing workflows in projects (categorised as the 2nd class of usage). However, digital project management solutions are less utilised for managing the budget, human resources, and procurement (categorised class 3 usage).

From Table 4 it is clear that project businesses in the South African mining sector mostly focus on the 1st class and 2nd class functionalities when having to adopt digital project management solutions. Some project businesses, however, are not making full use of digital project management tools.

**Table 4:** Levels of digital project management tools awareness and adoption

| | **Project businesses that use digital project management tools** | | | **Dichotomous scaling** | | | |
|---|---|---|---|---|---|---|---|
| **Class** | SPSS Coding | Variables | PM PHASE | N=49 | | | |
| | | | | YES | | NO | |
| | | | | % | Frequ-ency | % | Frequ-ency |
| **1st Class** | DQ3 | Use digital PM tools for planning in projects | Project planning | 95.90 | 47 | 4.10 | 2 |
| | DQ11 | Use digital PM tools for managing risks in projects | Project execution | 87.80 | 43 | 12.20 | 6 |
| | DQ12 | Use digital PM tools for managing safety in projects | Project execution | 91.80 | 45 | 8.20 | 4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2nd Class | DQ4 | Use digital PM tools for scheduling in projects | Project planning | 85.71 | 42 | 14.29 | 7 |
| | DQ7 | Use digital PM tools for time-tracking in projects | Project control & performance | 75.50 | 37 | 24.50 | 12 |
| | DQ8 | Use digital PM tools for Workflow Management in projects | Project execution | 75.50 | 37 | 24.50 | 12 |
| | DQ9 | Use digital PM tools for collaboration in projects | Project execution | 75.50 | 37 | 24.50 | 12 |
| 3rd Class | DQ5 | Use digital PM tools for budgeting projects | Project control & performance | 67.30 | 33 | 32.70 | 16 |
| | DQ6 | Use digital PM tools for human resource management in projects | Project control & performance | 69.40 | 34 | 30.60 | 15 |
| | DQ10 | Use digital PM tools for procurement purposes in projects | Project initiation | 59.20 | 29 | 40.80 | 20 |
| | Number of all respondents | | 49 | | | | |

Source: Researcher construct

Table 5 shows that the most used PMS package is Microsoft Project (representing 59.2%). The study by Magwali (2018:60) also revealed that Microsoft Project is the most well-known and commonly used system. Oracle Primavera (representing 8.5%), GanttPro (representing 8.5%) and Smart-sheet (representing 4.2%) PMS packages were also used. The 'Other' group of various software packages represents 16.9%. This group included Beltanalyst, Dynamicanalyst and Conveyer Design software; Business Intelligence (BI) Project and Asset Maintenance (AMT) Software; Drillsoft HDX; Focal Point and ERS Bio; 'GPM2 and SKF Project Tools; 'Liebherr Crane Planner 2.0; Monday.com; Microsoft Teams and TORAS-Techincal Operational Risk Assessment System. Huddle, Zoho Projects, BaseCamp and Trello software packages were the least-used packages in this study. The variety of choices is due to the preferences and knowledge of the digital project management tools, as well as the diversified scope of work of each project business.

Although there is not much information on the general use of various PMS packages, this study has shown that most project businesses prefer using independent and industry-specific systems.

**Table 5:** Most used project management software packages

| Project Management Software (PMS) Packages | Usage | |
|---|---|---|
| | Selection Frequency | Percentage |
| Trello package | 1 | 1.4% |
| BaseCamp package | - | - |
| Microsoft Project | 42 | 59.2% |
| Smart-sheet | 3 | 4.2% |
| Huddle | 1 | 1.4% |
| Oracle Primavera | 6 | 8.5% |
| Proofhub | - | - |
| Zoho Projects | - | - |
| GanttPro | 6 | 8.5% |
| Other | 12 | 16.9% |

Source: Researcher construct

Table 6 present data about the barriers to adopting digital project management tools. The table lists that most of the participants in this study supported the items that were used to determine the existence of the barriers to adopting digital project management solutions. Items that have higher values of 'strongly disagree' and 'disagree' include 'lack resources to use digital project management solutions', 'lack of knowledge about digital project management solutions', 'lack of technological experts to handle digital project management solutions' and 'complexity of processes in the mining sector' that represent a slight shift of unsupportiveness. However, from the data in Table 6, the most recognised barriers to adopting digital project management tools in the South African mining sector are the 'high costs associated with digital project management solutions' and 'uncertainty about the ROI of digital project management solutions.

**Table 6:** Analysis of the barriers to adopting digital project management solutions

| Code | Cronbach's test α: | CR: | AVE: | Scale | | | Results |
|---|---|---|---|---|---|---|---|
| | **0.800** | **0.979** | **0.403** | | | | |
| | **Items measured:** | | | **SD + D** | **N** | **SA + A** | **Supported/ unsupported** |
| **SDNAS1** | Lack of knowledge about digital project management solutions | | | 5 | 3 | 53 | Supported |
| **SDNAS2** | High costs associated with digital project management solutions | | | 3 | 2 | 56 | Supported |
| **SDNAS3** | Lack of resources to use digital project management solutions | | | 7 | 2 | 52 | Supported |
| **SDNAS4** | Lack technological experts to handle digital project management solutions | | | 5 | 2 | 54 | Supported |
| **SDNAS5** | Lack of information and popularity about digital project management solutions | | | 4 | 3 | 54 | Supported |
| **SDNAS6** | Lack of competition driven by the adoption of digital project management solutions | | | 2 | 5 | 54 | Supported |
| **SDNAS7** | Uncertainty about return on investment (ROI) of digital project management solutions | | | 2 | 3 | 56 | Supported |
| **SDNAS8** | Complexity of processes in the mining sector | | | 5 | 9 | 47 | Supported |

Source: Researcher construct

Table 7 reveals that most of the items herein were not supported by the participants of this study. The results show that most project businesses that participated are not fully ready to adopt digital project management tools.

From Tables 6 and 7 Cronbach's alpha coefficient values range from 0.800–0.932, implying that the items included in the tables have a high internal consistency. According to Tavakol and Dennick (2011:52), Almomani et al. (2018:5) and Taber (2018:1296), a Cronbach coefficient value >0.50 is acceptable and a value >0.91 is strong and reliable. The CR of the items in Table 6 of this study is 0.979 and in Table 7 it is 0.996, which indicates good CR values, as recommended by various researchers (Fornell and Larcker, 1981:46; Lam, 2012:1332; Huang et al. 2013:219; Yong and Pearce, 2013:80; Wipulanusat et al. 2017:64). The AVE value of 0.4 in Table 1.5 of this study is acceptable as it carries a CR value of 0.979, which Fornell and Larcker (1981:46), Lam (2012:1332) and Huang et al. (2013:219) confirm that it is ample to verify the existence of a valid connection among the items tested in this study. Table 1.6 displays an AVE value of 0.5 (with a CR value of 0.996).

**Table 7:** Analysis of the readiness to adopt digital project management solutions

| CODE: | **α:** | CR: | **AVE:** | SCALE | | | Sample size | RESULTS: |
|---|---|---|---|---|---|---|---|---|
| | | | | **SD + D** | **N** | **SA + A** | | **Supported/ Unsupported** |
| | 0.932 | **0.996** | 0.5 | | | | | |
| | **Items measured:** | | | | | | | |
| **SDNAS 9** | Recognise various digital project management solutions | | | 43 | 6 | 12 | 61 | Unsupported |
| **SDNAS 10** | Recognise opportunities and challenges of digital project management solutions | | | 44 | 4 | 13 | 61 | Unsupported |
| **SDNAS 11** | Recognise digital project management solutions that are applicable to the organisation | | | 44 | 3 | 14 | 61 | Unsupported |
| **SDNAS 12** | Recognise the benefits of digital project management solutions | | | 46 | 3 | 12 | 61 | Unsupported |
| **SDNAS 13** | Have a clear vision about implementing digital project management solutions | | | 50 | 4 | 7 | 61 | Unsupported |
| **SDNAS 14** | Have communicated the vision of implementing digital project management solutions throughout the organisation | | | 51 | 3 | 7 | 61 | Unsupported |
| **SDNAS 15** | Have defined roles, responsibilities and accountabilities regarding the adoption of digital project management solutions | | | 51 | 3 | 7 | 61 | Unsupported |
| **SDNAS 16** | Have enough technical skills (human capacity) to deploy and adopt digital project management solutions | | | 49 | 4 | 8 | 61 | Unsupported |
| **SDNAS 17** | Have evaluated the impact of digital project management solutions in the sector | | | 50 | 2 | 9 | 61 | Unsupported |
| **SDNAS 18** | Have sufficient resources to initiate the utilisation of digital project management solutions | | | 44 | 1 | 16 | 61 | Unsupported |
| **SDNAS 19** | Have the affordability to use digital project management solutions | | | 33 | 6 | 22 | 61 | Unsupported |
| **SDNAS 20** | Have analysed the organisational changes associated with the adoption of digital project management solutions | | | 49 | 5 | 7 | 61 | Unsupported |
| **SDNAS 21** | Staff members are ready for the changes associated with the adoption of digital project management solutions | | | 21 | 4 | 36 | 61 | Supported |
| **SDNAS 22** | Business data and transactions with employees online can be executed safely when using digital project management solutions | | | 30 | 7 | 24 | 61 | Unsupported |

Source: Researcher construct

## 5. DISCUSSION

The study aimed to investigate the awareness and adoption levels of digital project management tools and techniques among project businesses at the selected mine in the Limpopo Province. It has been revealed in this study that the level of awareness for digital project management tools is higher than the level of adoption. The data of this study suggested that experienced project businesses in the South African mining sector are more aware of digital project management tools than those that are less experienced. The results concur with Mazzarol et al. (2010:111) who discovered that businesses with high experience tend to adopt new technical systems as they have sufficient financial resources. The study also revealed that projects businesses which have not adopted digital project management tools experience internal challenges, such as lack of resources supported by Bhika and Pretorius (2019:488), limited budget supported by Murwira and Bekker (2017:141), and changes in project requirements (Kagogo and Steyn, 2019:266; Komal et al., 2020:17). Project businesses that have adopted digital project management tools face communication challenges in their project phases. External challenges such as economic changes and supplier-related issues were recognised as challenges that affected all project businesses, whereas unanticipated weather patterns only affected project businesses that have adopted digital project management tools. In relation to the above, McQuerrey (2019:1) stated that economic changes in South Africa affect project businesses on the four dimensions of high interest rates, high tax rates, low employment levels and low consumer expenditure. The research of Kafile and Fore (2018:185), Shehu et al. (2019:3) and Fourie and Malan (2020:13-14), added that the issue of suppliers is a constant challenge for South African project businesses. El-Sawalhi and Mahdi (2015:9) affirmed that severe weather patterns affect the project execution phase, as Ballesteros-Pérez et al. (2018:680) believes that construction project activities are more probable to be affected by weather conditions.

This study further discovered several barriers that affected project businesses which have not adopted digital project management tools which included: the lack of knowledge about digital project management solutions, the high costs associated with digital solutions, the lack of resources for using digital solutions, and the lack of technological expertise to handle digital project management tools. These barriers were also identified as factors that affected the readiness of project businesses to adopt digital project management tools.

## 6. CONCLUSION

Overall, this study revealed that the level of awareness of digital project management tools is higher than the level of adoption. Projects businesses that have not employed digital project management tools experience internal challenges, such as lack of resources, limited budget and changes in project requirements. The study contributed to extending the body of knowledge by clarifying that project businesses which have not employed digital project management tools noted poor communication as the greatest internal challenge that negatively affects their projects. The study further clarified that external challenges such as economic changes and supplier-related issues affected all project businesses. Unanticipated weather patterns affected only project businesses that employed digital project management tools. Discoveries in this study revealed that several barriers' tools such as: the lack of knowledge about digital project management solutions, the high costs associated with these solutions, a lack of resources for using these solutions and the lack of technological expertise to handle digital project management tools affected project businesses that did not employ digital project management. These barriers were also identified as factors that affected the readiness of project businesses to adopt digital project management tools. Several recommendations were listed in this study to help tackle the issues discovered in this study.

*Recommendations* - There are several recommendations derived from this study which are listed below:

- It is recommended that the South African business development agencies should consider offering ongoing training programmes that are focused on digitalisation and knowledge building in the discipline of project management.
- The South African mining sector should set a minimum standard requirement for project management training.
- Project businesses should invest in innovation and technology.
- Software developers should consider integrating with external systems that can enhance project management processes.

Below are recommendations that are listed in alignment with the limitations of this study. These recommendations are to be considered in future studies:

- A qualitative or longitudinal method of collecting data could be used in future research and investigations to collect further information regarding the use of digital project management tools.
- Future research and investigations could be based on experimental research design to investigate the implications of future developments of digital project management tools. A correlational research design could also be considered in future research when investigating the connection of numerous experiences among project businesses in different business sectors.
- Future studies could focus on different mining industries, business sectors and other developing countries.

*Limitations and future research* - Several limitations were identified that have implications for future investigations and research projects:

- The research instrument of this study was closed-ended, thereby rendering the research methodology of this research to be quantitative, which restricted the opinions of the respondents.
- This study was based on a case study method, which focused on a limited group of project businesses in a restricted location of the Limpopo Province of South Africa.
- The study was also conducted in an opencast platinum mine region and cannot be generalised, as such empirical findings in different mining industries and other business sectors are needed.

## REFERENCES

Adriaanse, A., Voordijk, H. and Dewulf, G. (2010). The use of interorganisational ICT in United States 0construction projects. Automation in Construction, 19(1), 73–83.

Al Shaer, S. 2018. Expected monetary value – EMV. https://eliteminds.co/2018/11/27/expected-monetary-value-emv/[24 September 2020].

Ali, A.S.B., Anbari, F.T. and Money, W.H. (2008). Impact of organizational and project factors on acceptance and usage of project management software and perceived project success. Project Management Journal, 39, 5–33.

Almomani, F., Tamara, A., Naor, D., Naomi, J. and Murad, A.O. (2018). Construct validity an internal consistency reliability of the Loewenstein occupational therapy cognitive assessment (LOTCA). BioMed Psychiatry, 18(Article 184), 1–9.

Arnold, P, and Javernick-Will, A. (2013). Project-wide access: Key to effective implementation of construction project management software systems. Journal of Construction Engineering and Management, 139, 510–518.

Aubert, B.A. and Reich, B.H. (2009). Extracting value from information technologies, CIRANO Burgundy Reports. 2009rb-04, CIRANO. https://ideas.repec.org/p/cir/cirbur/2009rb-04.html. [2 May 2019].

Ballesteros-Pérez, P., Smith, S.T., Lloyd-Papworth, J.G. and Cooke, P. (2018). Incorporating the effect of weather in construction scheduling and management with sine wave curves: Application in the United Kingdom. Construction Management and Economics, 36(12), 666–682.

Bardhan, I.R., Krishnan, V.V. and Lin, S.S. (2007). Project Performance and the Enabling Role of Information Technology: An Exploratory Study on the Role of Alignment. Manufacturing and Service Operations Management, 9, 579–595.

Bedneko, O. (2019). Top 5 project management software. https://www.bitrix24.com/articles/ttop-5-project-management-software.php [31 March 2020].

Bhika, B. and Pretorius, J.H.C. (2019). Challenges facing projects due to a lack of resources. Proceedings of the International Conference on Industrial Engineering and Operations Management, 23–26 July 2019. Pilsen, Czech Republic: IEOM Society International, 485–494.

Borštnar, M.K. and Andreja, P. (2014). Impacts of the implementation of a project management information system – a case study of a small RandD company. Research Papers, 47(1), 14–23.

Bresnahan, T.F., Brynjolfsson, E. and Hitt, L.M. (2002). Information technology, workplace organization and the demand for skilled labor: Firm-level evidence. Quarterly Journal of Economics, 117, 339–376.

Bryde, D.J. and Wright, G.H. (2007). Project management priorities and the link performance management systems. Project Management Journal, 38, 5–11.

Brynjolfsson, E. and Yang, S. (1996). information technology and productivity: A review of the literature. Advances in Computers, 43, 1–70.

Daniel, E. (2016). The usefulness of qualitative and quantitative approaches and methods in researching problem-solving ability in science education curriculum. Journal of Education and Practice, 15(7), 91–100.

Dewett, T. and Gareth, R.J. (2001). The role of information technology in the organization: A review, model and assessment. Journal of Management, 27, 313–348.

Dostie, B. and Jayaraman, R. (2008). Organizational redesign, information technologies and workplace productivity. SSRN Electronic Journal, 12(1), 1–43. https://www.researchersgate.net/publication/23528894_Organizational_Redesign_Information_Technologies_and_Workplace_Productivity [25 June 2020].

Elkatawneh, H. (2016). Comparing qualitative and quantitative approaches. SSRN Electonic Journal, 1–5. DOI: 10.2139/ssrn.2742779.

El-Sawalhi, N. and Mahdi, M. (2015). Influence of climate change on the lifecycle of construction projects at Gaza strip. Journal of Construction Engineering and Project Management, 5(2), 1–10.

Etikan, I., Musa, S.A. and Alkassim, R.S. (2016). Comparison of convenience sampling and purposive sampling. American Journal of Theoretical and Applied Statistics, 5(1), 1–4.

Fornell, C. and Larcker, D.F. (1981). Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research, 18, 39–50.

Fourie, D. and Malan, C. (2020). Public procurement in South African economy: Addressing the systemic issues. Sustainability, 12(20): 8692. https://doi.org/10.3390/su12208692 [21 March 2021].

Gustavsson, T.K., Samuelson, O. and Wikforss, Ö. (2012). Organizing it in construction: present state and future challenges in Sweden. Journal of Information Technology in Construction, 17, 520–523.

Hajjaji, M., Denton, P. and Jackson, S. (2010). The effectiveness of using project management tools and techniques for delivering projects. In: Proceedings of Computing and Engineering Annual Researchers' Conference 2010: CEARC'10. University of Huddersfield, Huddersfield: 124-129. ISBN 9781862180932.

Hassan, I. and Asghar, S. (2021). A framework of software project scope definition elements: an ISM-DEMATEL approach. Institute of Electrical and Electronics Engineers, 9:26839–26870.

Huang, C., Wang, Y., Wu, T. and Wang, P. (2013). An empirical analysis of antecedents and performance consequence of using the Moodle platform. International Journal of Information and Education Technology, 3(2), 217–221.

Kafile, M. and Fore, S. (2018). Effects of procurement process on project execution in a project management company in Cape Town South Africa. International Journal of Business and Administrative Studies, 4(4), 176–186.

Kagogo, T.S. and Steyn, H. (2019). Effect of scope readiness on capital projects in mining: A Namibian case study. South African Journal of Industrial Engineering, 30(1), 257–269.

Kashyap, S. (2018). The importance of project management software to improve team productivity. https://www.proofhub.com/articles/importance-of-project-management-software [31 March 2020].

Klynveld Peat Marwick Goerdeler (KPMG), Australian Institute of Project Management (AIPM) and International Project Management Association (IPMA). (2019). The future of project management: global outlook 2019. Amstelveen, Netherlands: KPMG, AIPM and IPMA.

Komal, B., Janjua, U., Anwar, F., Madni, T.M., Cheema, M.F., Malik, M.N. and Shahid, A.R. (2020). The impact of scope creep on project success: Empirical investigation. IEEE Access, 8:125755–125775. DOI: 10.1109/ACCESS.2020.3007098 [21 March 2021].

KPMG see Klynveld Peat Marwick Goerdeler.

Kuvshinikov, M., Pijkul, P. and Samek, R. (2017). Getting big mining projects right: Lessons from and for the industry. https://www.mckinsey.com/industries/metals-and-mining/our-insights/getting-big-mining-projects-right-lessons-from-and-for-the-industry [14 March 2020].

Lam, L.W. (2012). Impact of competitiveness on salespeople's commitment and performance. Journal of Business Research, 65:1328–1334.

Lan, P. (2018). A review of key paradigms: Positivism, interpretivism and critical inquiry. The University of Adelaide, Chapter XX,1–7. DOI: 10.13140/RG.2.2.13995.54569 https://www.researchgate.net/publication/324486854_A_Review_of_key_paradigms_positivism_interpretivism_and_critical_inquiry [26 December 2020].

Magwali, S.N. (2018). Application of project management software and its influence on project success: A case of NPOs in the Western Cape. Unpublished MTech thesis, Cape Peninsula University of Technology, Cape Town.

Mazzarol, T., Reboud, S. and Volery, T. (2010). The influence of size, age and growth on innovation management in small firms. International Journal of Technology, 52(1), 98–117.

McGrath, J. and Kostalova, J. (2020). Project management trends and new challenges 2020+. In Jedlicka, P., Maresova, P., Firlej, K. and Soukal, S. (eds). 2020. Proceedings of 18th International Conference Hradec Economic Days 2020, 2–3 April 2020, Hradec Kralove, Czecy. Hradec Kralove: University of Hradec Kralove: 534–542. http://dx.doi.org/10.36689/uhk/hed/2020-01-000 [6 October 2020].

McQuerrey, L. (2019). The economy's effects on small businesses. https://smallbusiness.chron.com.economys-effects-small-businesses-10269.html [18 March 2021].

Murwira, D. and Bekker, M. (2017). Building an infrastructure project performance in the North-West Province Department of Public Works Roads. Acta Structilia, 24(2), 128–145.
Palisade. (2010). @RISK customer testimonials. http://www.palisade.com/risk/testimonials_risk.asp[03 May 2020].
Pellerin, R., Perrier, N., Guillot, X. and Léger, P.M. (2013). Project characteristics, project management software utilization and project performance: An impact analysis based on real project data. International Journal of Information Systems and Project Management, 1(3), 5–26.
PriceWaterhouse Coopers (PWC). (2012). Insights and trends: current program and project management practices: The second global survey on the current state of project management maturity in organisations across the world. McLean, VA: PWC.
Puška, A., Stojanović, I., Maksimović, A. and Osmanović, N. (2020). Project management software evaluation by using the measurement of alternatives and ranking accosting to compromise solution Marcos method. Operational Research in Engineering Sciences: Theory and Applications, 3(1), 89–102.
Rahl, S. (2017). Research design and methods: a systematic review of research paradigms, sampling issues and instruments development. International Journal of Economics and Management Sciences, 8(2), 1–5.
Raymond, L. and Bergeron, F. (2007). Project management information systems: An empirical study of their impact on project managers and project success. International Journal of Project Management, 26(2), 213–220.
Sajad, M., Sadiq, M., Naveed, K. and Iqbal, M.S. (2016). Software project management: Tools assessment, comparison and suggestions for future development. International Journal of Computer and Network Security, 16(1), 31–42.
Shehu, A., Ibrahim, Y. and Inuwa, I. (2019). Knowledge requirement theoretical framework for construction procurement management. In Proceedings of 7th International Conference on Euro Asia Civil Engineering forum, 30 September – 02 October 2019. Stuttgart, Germany: IOP Publishing: 1–8.
Son, H., Park, Y., Kim, C. and Chou, J.S. (2012). Toward an understanding of construction professionals' acceptance of mobile computing devices in South Korea: An extension of the technology acceptance model. Automation in Construction, 28, 82–90. DOI: 10.1016/j.autcon.2012.07.002.
Taber, K.S. (2018). The use of Cronbach's Alpha when developing and reporting research instruments in science education. Research Science Education, (48), 1273–1296.
Tavakol, M. and Dennick, R. (2011). Making sense of Cronbach's Alpha. International Journal of Medical Education, (2), 53–55.
Trochim, W.M.K. (2020). Research methods knowledge base. https://conjointly.com/kb/nonprobability-sampling/[29 November 2020].
Wellingtone. (2018). Annual report: the state of project management 2018. Australia: Wellingtone.
Wellingtone. (2020). Annual report: the state of project management 2020. Hobart, Tasmania, Australia: Wellington Bridge Press.
Wilkinson, D. and Birmingham, P. (2003). Using research instruments, a guide for researchers. Abingdon, UK: Routledge.
Wipulanusat, W., Panuwatwanich, K. and Stewart, R. (2017). Workplace innovation: exploratory and confirmatory factor analysis for construct validation. Management and Production Engineering Review, 8(2), 57–58.
Wright, S., O'Brien, S.C., Nimmon, L., Law, M. and Mylopoulos, M. (2016). Research design considerations. Journal of Graduate Medical Education, 8(1), 97–98.
Yong, A.G. and Pearce, S. (2013). A beginner's guide to factor analysis: Focusing on exploratory factor analysis. Tutorials in Quantitative Methods for Psychology, 9(2), 72–94.

Journal of Construction Project Management and Innovation, 12(1): 55-64, 2022
ISSN 2223-7852


# Factors facilitating effective knowledge spillovers from foreign to domestic construction firms in Abuja, Nigeria

**Olorunfemi Bamisaye[1], Najimu Saka[2], and Taiwo Fadeke Adegbembo[3]**

[1,2&3]Department of Quantity Surveying, School of Environmental Technology, Federal University of Technology, Akure, Ondo State, Nigeria

Email: 2010bampaul@gmail.com; nsaka@futa.edu.ng; tfadegbembo@futa.edu.ng

## ABSTRACT
The potential benefits of Foreign Direct Investment (FDI) on the host economy are capital inflows, job creation and most importantly, knowledge spillovers. The purpose of this study was to assess the key factors that facilitate effective knowledge spillovers from foreign construction firms to local construction firms. Data were collected through the use of a well-structured questionnaire. It was administered to construction professionals in both foreign and domestic construction firms in Abuja, Nigeria. The data were analysed using descriptive and inferential statistical tools. It was revealed in the study that ICT, access to finance, the skill of workers and employee motivation were the key factors responsible for effective knowledge spillovers. Hence, it was recommended that domestic firms should fully harness the key factors responsible for effective knowledge spillovers, as this will enable them to widen their knowledge spectrum and not become trapped in their current expertise. Also, the government should make and enforce policies that will encourage knowledge spillovers.

**Keywords:** Knowledge spillovers; Foreign Direct Investment (FDI); Foreign Construction Firms; Domestic Construction Firms.

## 1. INTRODUCTION
Construction is the backbone of development, and without an efficient and functional construction industry, no country can think dream, or experience development (Idoro, 2014). According to Alintah-Abel and Nnadi (2016), the industry is virtually widely considered as the core of every other sector of any country's economy, and this is why when the industry sneezes, the economy catches a cold. In same vein, Omole (2000) revealed that the Nigerian construction industry is the driving force behind the country's economic growth.

According to Cyrielle and Xiaolan (2015), Foreign Direct Investment (FDI) has long been seen as a significant driver of economic progress in developing countries. FDI is not only seen as a requirement for growth strategies in Sub-Saharan Africa (SSA) and other developing countries, but it is also widely accepted that FDI boosts local firms' productivity. When foreign firms invest in a host country, they often bring their unique technology. Many governments have implemented policies to encourage FDI by providing substantial financial incentives based on the notion that local firms will profit from knowledge transfer (Merlevede et al., 2014). Muyendi and Njuru (2016) stated that any firm with a high level of productivity entering the market should naturally stimulate other firms in the same sector to increase their performance and competitiveness. Increased production efficiency can be achieved by imitating innovative technologies or hiring trained workers and managers from foreign firms (Javorcik 2004). In addition, firms from other sectors may be affected by the presence of foreign firms. These include firms that supply or provide services to foreign firms. Furthermore, better standards offered by foreign firms to local firms are likely to boost the efficiency and performance of local firms. Capital inflows, job creation, and, most significantly, knowledge spillovers are all potential benefits of FDI for the host economy.

According to Adegbembo, Awodele and Oke (2020), the construction industry is one which greatly uses the skills, experience and abilities of its employee within the organisation. As a result of the nature of the industry, which may involve professionals from within and outside an organisation, the industry is prone to knowledge spill. Knowledge spillovers, as posited by Fallah and Ibrahim (2004) are the unintentional transmission of knowledge to others beyond the intended boundary. Any knowledge that is exchanged outside the intended boundary is spillover. Once this knowledge is out there, it can be used in a variety of ways to assist other people's work and may even lead to discoveries. Moreover, knowledge spillovers occur when recipient firms make use of knowledge developed by the originating firm (Yang and Steensma 2014). These recipient firms could be alliance partners, direct competitors of the originating firm, or firms from different sectors. Whatever the case, when recipient firms take advantage of the originating firm's knowledge, they frequently merge it with other knowledge to produce their own distinctive inventions (Sorenson et al.2006).

Furthermore, Crespo et al.(2007) stated that spillovers also happen when Multinational Corporations (MNCs) are unable to fully internalise their stock of knowledge (which includes technology and management practices), allowing domestic firms to benefit from it. Osabutey et al. (2014) stated that the ability of foreign firms to transfer knowledge to local firms in the host countries is one of the key benefits of FDI. This calls for regular and intense interaction between the source and the recipient (McDermott and Corredoira, 2010). According to Cyrielle and Xiaolan (2015), knowledge spillovers boost domestic productivity, promote economic growth, and help developing countries escape poverty. When firms rely solely on their current expertise, they get caught within their limited knowledge areas and run the risk of just replicating their own expertise (Yang and Steensma 2014). Firms must seek knowledge outside of their present expertise to avoid becoming too restricted. If a firm's present expertise isn't enough to keep it afloat, it may be necessary to look for knowledge from areas outside its own (Sorenson et al. 2006).

## 2. LITERATURE REVIEW

### 2.1 Theoretical framework on knowledge spillovers

*Theory of Learning by Doing* - Sorensson (2010) stated that knowledge must be gained. It is self-evident that knowledge increases over time. Learning is the term used to describe the process of acquiring knowledge. Arrow (1962) exploits the learning-by-doing theory. This simply means that one producer's activities may/can lead to the productivity of another simply by learning and doing what the first producer has done. This refers to the spillover of knowledge between producers. The level of technology can now be influenced by individual producers themselves by R and D activities.

*Marshall-Arrow-Romer (MAR) Theory* - According to Sorensson (2010), the corresponding knowledge spillover in a localisation setting is commonly referred to as Marshall-Arrow-Romer (MAR) externalities (in reference to Marshall (1890), Arrow (1962), and Romer (1990)). This focuses on knowledge spillovers within the same industry, where concentration in a specific region fosters knowledge spillovers between firms and, as a result, economic growth. The MAR theory was developed in 1980 by an English economist named Alfred Marshall, and it was later extended by these economists, Kenneth Arrow in 1962 and Paul Romer in 1986. The MAR views on knowledge spillovers were gathered and called the MAR spillovers by Glaeser et al. (1992). According to the MAR spillover theory, the proximity of firms within a similar industry significantly impacts how well information travels among firms to support innovation and growth. This means that as firms move closer to one another, the MAR spillover increases. The exchange of ideas is mostly from employee to employee, that is, employees from different firms in an industry share ideas on products, innovations, and new ways to produce items. New goods and improved production methods are the focus of the opportunity to exchange ideas that lead to advancements. Carlino (2001) cited several semiconductor companies that purposefully situated their R&D centers in Silicon Valley, California, USA, an industrial location, to take advantage of MAR spillovers. Furthermore, the film industry in Los Angeles, California, and other places rely on a geographic concentration of specialists such as directors, producers, scriptwriters, set designers, and other professionals to bring diverse components of filmmaking together into a finished product.

*Jacob Spillover Theory* - Jacobs (1969) emphasised that the importance of diversity in the urban industry mix is directly linked to urbanisation economies, particularly in terms of the growth impacts caused by information spillovers. A broad industry mix in a given location increases the chance of exchanging, imitating, modifying, and recombining products, processes, or ideas, implying that diversity could be a source of knowledge spillover that spurs growth. Under Jacob's spillover view, the proximity of firms from different industries impacts how successfully knowledge flows among firms to facilitate innovation and growth. This is in disparity with MAR spillovers which focus on firms in a common industry (Carlino 2001). The Jacob's spillover's diversified proximity brings together ideas from individuals with diverse views to enable an interchange of ideas and create innovation in a diverse industrial setting.

*Porter Spillover Theory* - Porter (1990) proposes a concept that is similar to MAR in that it stresses concentration within the same industry as the major channel for firm spillover. Knowledge spillovers in specialised geographically concentrated industries enhance growth. However, he emphasises that local competition, rather than local monopoly, encourages the pursuit and quick acceptance of innovation as well as the transmission of local information. In the same line, he emphasises the importance of local competition of ideas in promoting growth through increasing adoption of innovation, using the ceramics and gold jewelry industries in Italy as examples of industries where hundreds of enterprises are clustered and aggressively compete to innovate. In cities with geographically specialised, competitive industries, Porter spillovers are maximised.

## 2.2 Factors facilitating effective knowledge spillovers

*Learning/Training* - Osabutey and Jin (2016) stated that knowledge spillovers could be influenced by learning, which is a result of educational systems. As a result, knowledge transfer should include a purposeful effort on the part of local firms to acquire, store, generate, transmit, and build upon or add to knowledge, which is related to the Knowledge Management (KM) concept. The recipient's ability to absorb information is crucial to learning.

*Skill of Workers* - According to Crespo et al. (2007), foreign firms do business with local firms that make high-quality goods because expertise is linked to high-quality goods. Skilled workers in local firms can learn new production processes and technology from workers in foreign firms, which indicates that they have a better absorption capacity. Koen and Bartoldus (2002) also stated that Local high-skilled workers can obtain training from foreign firms' workers, which improves their productivity and quality of output. Therefore, it was concluded in the study of Muyendi and Njuru (2016) that the skills of domestic firms' employees are a crucial factor of their ability to attract both vertical and horizontal spillovers.

*Geographical Proximity of Local Firms to Foreign Firms* - According to Binyam and Syed (2018), it was stated that when local firms are physically close to foreign firms, they tend to gain. The major reason for this is that spillover transmission channels are reinforced first by neighbouring firms and then expand to firms that are geographically further away. As a result, the potential of spillover transmission decreases as distance increases.

*Availability of Deeper and Stronger Financial Markets* - According to TeVelde (2019), deeper and stronger financial markets encourage spillover. Suppliers, imitators, learners, and competitors can invest in technology and human capital to improve spillovers when capital markets are better and functioning. Local firms become less reliant on and trapped in captive supply/value chain linkages as the financial sector develops. Although linkages are beneficial in and of themselves, the ability to diversify and develop new linkages and enhance value chains through access to finance may optimise learning. Thus, Local firms are motivated to act by foreign firms, and they can respond to opportunities if they have the resources to do so. Access to finance helps them in this situation. Local firms will be able to adapt to rising foreign competition with the help of a more established financial market.

*Employees' Motivation* - According to Zafar, et al. (2014), employee's motivation is essential for achieving efficiency. Motivation is a collection of factors influencing an employee's behaviour to achieve a specific objective. Motivation is necessary to encourage individuals to perform effectively in the long run and to assist an organisation in achieving excellence. Even though motivating people is a difficult task, if employees are motivated, they will be satisfied with their jobs, and if they are satisfied with their jobs, they will work hard to reach organisational goals, which will result in profit for the organisation. An organisation must have a reward management system in place to evaluate the performance of employees since this system has a motivating effect on retaining employees and achieving high levels of performance.

*Digital Infrastructure* - According to TeVelde (2019), a lack of digital infrastructure is one reason why spillovers through subcontractor linkages frequently fail to materialise. A better digital infrastructure (e.g., access to the internet and digital platforms) will entice more digital foreign firms (Banga and TeVelde, 2018). Such firms have a lot of knowledge and hence greater potential for spillovers to local firms. Digital infrastructure can also help form clusters, which fosters knowledge spillovers TeVelde (2019). Based on a survey of Hong Kong garment firms in China, the study by Thompson (2002) showed that clustered FDI is substantially better than scattered FDI at transferring technology, implying that industry clustering should be considered.

## 3. METHODOLOGY

The research adopted the survey design approach. The research involved the population of construction professionals in some construction firms. The target respondents included quantity surveyors, architects, engineers, builders and other professionals. The location of the study was Abuja, Nigeria; this was based on the fact that Abuja is prominent for construction activities and the headquarters for most foreign and local construction firms. In this study, questionnaires were used in collating data from the respondents. The preliminary section of the questionnaire centred on the respondents' demographic information, while the second section centred on the key factors that facilitate effective knowledge spillovers. The questions were asked on a 5-point scale, with five being the highest rating. Statistical method was used to analyse the collected data using the Statistical Package for the Social Sciences (SPSS) software package. The statistical methods used were percentile to analyse the background information of respondents, while the Mean Item Score (MIS) and standard deviation were used to rank the key factors responsible for effective knowledge spillovers.

## 4. DATA ANALYSIS AND RESULT

A total number of one hundred and fifteen (115) copies of the questionnaire were distributed within the survey area, out of which eighty-four (84) were retrieved and considered good enough for analysis, amounting to seventy-three (73) per cent response rate. The collected data were analysed and represented in tables. It is shown in table1that 31percent of the respondents are Quantity Surveyors, 15.5 per cent are Architects, 10.7 per cent are builders, 40.7 per cent are Engineers, and 2.4 percent belong to other professionals. This depicts that the respondents cut across every profession in the construction industry and are competent enough to provide suitable and reliable data needed to achieve the purpose of the study. In addition, it can be noticed that 60.7 per cent of the respondents have more than ten years of working experience. Also, 88.1 per cent of the respondents work with an indigenous construction firm, while 11.9 per cent work with a foreign construction firm. Also, 32.1 per cent of the 88.1 per cent of the respondents who work with various domestic firms claimed to have previously worked with one foreign construction firm or the other. Meanwhile, 96.4 per cent of the respondents are Nigerian, while 3.6 per cent are foreigners.

**Table 1.** Demographic information of respondents

| Variables | Classification | Frequency | Percent |
|---|---|---|---|
| Profession of Respondent | Quantity Surveyor | 26 | 31.0 |
| | Architect | 13 | 15.5 |
| | Builder | 9 | 10.7 |
| | Engineer | 34 | 40.5 |
| | Others | 2 | 2.4 |
| | **Total** | **84** | **100.0** |
| Years of Experience | 1-5 | 16 | 19.0 |
| | 6-10 | 17 | 20.2 |
| | 11-15 | 17 | 20.2 |
| | 16-20 | 14 | 16.7 |
| | Above 20 | 20 | 23.8 |
| | **Total** | **84** | **100.0** |
| Employer | Domestic | 74 | 88.1 |
| | Foreign | 10 | 11.9 |
| | **Total** | **84** | **100.0** |
| For the domestic employees, ever worked with a foreign firm before? | Yes | 27 | 32.1 |
| | No | 47 | 56.0 |
| | **Total** | **74** | **88.1** |
| Nationality | Nigerian | 81 | 96.4 |
| | Foreigner | 3 | 3.6 |
| | **Total** | **84** | **100.0** |

### 4.1 Mean ranking for factors that facilitate effective spillover

Table 2 shows the mean ranking of the factors that facilitate effective knowledge spillovers. ICT, with a mean value of 3.76 and a SD value of 1.209 is the highest factor that facilitates knowledge spillovers. It is followed by access to finance with a mean score of 3.74 and a SD value of 1.077 while skill of local workers followed with a mean value of 3.73 and a SD value of 0.923. The least ranked of the factors is age of local firm with a mean value of 3.07 and SD value of 1.138.

**Table 2**: Mean ranking for factors that facilitate effective spillover

| Factors | Mean | SD | Rank |
|---|---|---|---|
| ICT | 3.76 | 1.209 | 1 |
| Access to finance | 3.74 | 1.077 | 2 |
| Skill of local workers | 3.73 | .923 | 3 |
| Employee's motivation (Incentives) | 3.71 | 1.048 | 4 |
| Training of local workers by foreign corporations | 3.70 | 1.095 | 5 |
| Adoption of local content policy in the construction industry | 3.69 | 1.053 | 6 |
| Attracting more FDI into the country | 3.63 | 1.062 | 7 |
| Strong technological capacity of a local firm | 3.58 | 1.204 | 8 |
| Frequent and intensive interaction between foreign and local contractors | 3.52 | 1.114 | 9 |
| R&D emphasis on both local and foreign firms | 3.52 | 1.124 | 10 |
| Consistent jobs for local contractors from the government | 3.46 | 1.246 | 11 |
| Size of local firm | 3.43 | 1.021 | 12 |
| Competition policy | 3.43 | 1.056 | 13 |
| Strong innovative capacity of local firms | 3.42 | 1.184 | 14 |
| Availability of deeper and stronger financial market for local firms | 3.42 | 1.224 | 15 |
| Geographical proximity/nearness of local firms to foreign firms | 3.31 | 1.251 | 16 |
| Strong legal system | 3.29 | 1.059 | 17 |
| Age of local firm | 3.07 | 1.138 | 18 |

### 4.2 Factor analysis for factors that facilitate effective spillover

Each Factor was named by using a name that reflects all the variables. And where there was difficulty in picking a suitable name, the variable(s) that has the highest factor loadings among all the variables that loaded onto a factor was used in naming that factor. The three factor groupings are reported as follows.

- Nine (9) variables loaded onto factor 1, as shown in table 3, which indicates that these variables are identified as the topmost factors that facilitate effective knowledge spillovers. This factor loads 'frequent and intensive interaction between foreign and local contractors', 'strong technological capacity of a local firm', 'size of local firm', 'Skill of local workers', 'geographical proximity/nearness of local firms to foreign firms', 'age of local firm', 'availability of deeper and stronger financial market for local firms', 'strong innovative capacity of local firms' and 'R&D emphasis on both local and foreign firms'. Therefore, they are collectively called the 'Capacity factor'.
- A total of four (4) variables were loaded under Factor 2, as shown in table 3. This factor loads 'Attracting more FDI into the country', 'Training of local workers by foreign corporations', 'Competition policy' and 'Digital infrastructure (ICT)'. They were collectively named 'Attraction factor'.
- Five (5) variables are loaded in Factor 3, as shown in Table 3. This factor loads 'adoption of local content policy in the construction industry', 'consistent jobs for local contractors from the government', 'access to finance', 'employee's motivation (Incentives)', 'strong legal system'. Therefore, they were collectively called 'Motivation factor'.

**Table 3**: Reduced component for the factors that facilitates knowledge spillovers

| Components | Variables | Factor loadings |
|---|---|---|
| Capacity factor | Frequent and intensive interaction between foreign and local contractors | 0.757 |
| | Strong technological capacity of a local firm | 0.754 |
| | Size of local firm | 0.709 |
| | Skill of local workers | 0.676 |

| | | |
|---|---|---|
| | Geographical proximity/nearness of local firms to foreign firms | 0.654 |
| | Age of local firm | 0.653 |
| | Availability of deeper and stronger financial market for local firms | 0.605 |
| | Strong innovative capacity of local firms | 0.593 |
| | R&D emphasis on both local and foreign firms | 0.515 |
| Attraction factor | Attracting more FDI into the country | 0.706 |
| | Training of local workers by foreign corporations | 0.702 |
| | Competition policy | 0.551 |
| | ICT | 0.550 |
| Motivation factor | Adoption of local content policy in the construction industry | 0.725 |
| | Consistent jobs for local contractors from the government | 0.621 |
| | Access to finance | 0.590 |
| | Employee's motivation (Incentives) | 0.570 |
| | Strong legal system | 0.562 |

### 4.3 Discussion of Result

ICT ranked high as one of the key factors that facilitate effective knowledge spillovers from foreign firm to local firms. This loads under the 'Attraction factor' component in the factor analysis. This is in agreement with the study of Hamad (2018) which stated that ICT has been critical in facilitating knowledge spillovers from one location to another around the world. ICT is a useful instrument for transferring or exchanging knowledge because it allows geographically dispersed people and teams to communicate successfully regardless of distance. Arreymbi et al. (2008) also mentioned that it accelerates fast information access by firms. Ha et al. (2016) supported this idea that ICT is a useful tool for faster response time and gaining access to information. With ICT, firms' information can be assessed and obtained for an organisation's usage. Nasimi et al. (2013) stated that ICT allows for the acquisition of information through the use of networks and databases. One of the transmission channels through which technology can be distributed between firms, regions, and countries is through the media and the internet (Fu et al. 2010).

In the study, access to finance was also a top key factor that facilitates knowledge spillovers. This factor was seen to load under the 'Motivation factor' component in the factor analysis. According to Ozturk and Mrkaic (2014), access to finance can be referred to as the availability of finance in the form of bank loans, trade credit, equity, debt securities, and other external sources. Having access to finance is an important determinant for enterprises' development. This agrees with Thanh et al. (2011) that financial assistance, such as loans from financial institutions, has aided small and medium enterprises in their operations. With access to finance, domestic firms will be able to easily improve their technological and management abilities to remain competitive. This goes in line with the findings of Rupeika-Apoga and Solovjova (2017), which confirmed that firms that have access to loans develop more quickly than those that do not.

Skill of local workers has also been seen as one of the factors that can be responsible for knowledge spillovers. This loads under the 'Capacity factor' component of factor analysis. The technical and managerial skills of workers will make knowledge spill over rapidly. This supports the study of Mason (2018) that building and acquiring skills is a critical component of a firm's ability to absorb and exploit ideas and technology from other sources. The study further explained that for a firm to imitate the results of innovation carried out by other firms, they need a workforce with the relevant skills and knowledge for research, development and innovation, as well as the ability to turn innovations acquired from outside sources into increased productivity. The study by Keller (1996) stated that economic historians stress that technological catch-up necessitates better labour force skills which was also supported by UNCTAD (2006) that technology and managerial skills are one of the factors that enable small and medium enterprises (SMEs) to compete in the global market place. Also, from the study of Jude (2015) carried out on Romania workforce, it was discovered that workers' high skill level might boost domestic firms' ability to profit from knowledge spillovers.

It can also be seen that employee motivation is one of the factors that help facilitate effective knowledge spillovers. When local employees are motivated, it propels them to want to go all the way out in search of knowledge and do anything possible to make their organisation grow. This assertion was supported by Zafar et al. (2014) that increasing competition forces firms to have highly skilled, motivated and loyal employees who work for the success of the firm. Employee's motivation is compulsory for achieving efficiency and also important to help an organisation grow for excellence. The study further stated that motivation comes in two different rewards; extrinsic and intrinsic rewards. Extrinsic rewards can be in the form of salary/pay, incentives and bonuses, while intrinsic rewards are intangible like appreciation, caring attitudes from employers and job rotation.

## 5. CONCLUSION AND RECOMMENDATION

The study assessed the factors that facilitate effective knowledge spillovers in the Nigerian construction industry. From the study, it was discovered that Information Communication Technology (ICT), access to finance, skill of local workers and employee's motivation are the key factors that can facilitate effective knowledge spillovers. Furthermore, all the factors were clustered into three major components. If these important components are well addressed by both the government and domestic contractors, the qualities of the foreign firms will be possessed by the domestic firms and in the long run, the Nigerian government may not be needing the services of the foreign firms because by then, the Nigerian construction industry will be fully internalised. It is also recommended that domestic contractors should use ICT facilities to their own advantage in other to source for latest technologies and knowledge used in the industry. Also, the government should make funds easily accessible to local contractors so that they can be able to acquire advanced technologies for their tasks. The domestic firms should make possible effort to upgrade the skills of its workers as this will further boost the absorptive capacity of the firm. Motivation of workers should also be the top priority for domestic firms as this in turn increases the efficiency of workers. Also, the government should also enforce interaction between the foreign and domestic contractors in the form of linkages.

## REFERENCES

Adegbembo T. F, Awodele, O. A and Oke A. E. (2020) A principal component analysis of knowledge management success factors in construction firms in Nigeria. Journal of Construction Project Management and Innovation, 10 (1), 42-54

Aitken, B., A.Harrison, and Lipsey, R. E. (1996). Wages and foreign ownership a comparative study of Mexico, Venezuela and the United States. Journal of International Economics, 40(3), 345–371.

Alintah-Abel, U., and Nnadi, E. (2016). The assessment of foreign construction firms' participation on the cost of construction works in Nigeria.

Arreymbi, J., Agbor, A., and Adnan, A. (2008). Critical analysis of why ICT uptake is slow in emerging economies -the case of Cameroon . Advances in Computing and Technology, The School of Computing and Technology 3rd Annual conference, (p. 165). London.

Arrow, K. J. (1962). The economic implications of learning by doing. The Review of Economic Studies, 29(3), 155-173.

Banga, K., and Te Velde, D. (2018). Digitalisation and the future of manufacturing in Africa. London: ODI Papers.

Binyam, A. D., and Syed, M. M. (2018). Transmission channels matter: Identifying spillovers from FDI. The Journal of International Trade and Economic Development, 27(7), 701-728.

Carlino, G. A. (2001). Knowledge spillovers: Cities' role in the new economy. Business Review, Federal Reserve Bank of Philadelphia, 1(4), 17-26.

Crespo, Nuno, and Maria. (2007). Determinant factors of FDI spillovers–what do we really know? World Development, 410-425.

Cyrielle, A., and Xiaolan, F. (2015). Chinese MNEs and managerial knowledge transfer in Africa: the case of the construction sector in Ghana. Journal of Chinese Economic and Business Studies, 13(4), 285-310.

Fallah, M. H., and Ibrahim, S. (2004). Knowledge spillover and innovation in technological clusters. IAMOT.

Fu, X., Pietrobelli, C., and Soete, L. (2010). The role of foreign technology and indigenous innovation in emerging economies: technological change and catching up. Washington D.C: Inter-American Development Bank.

Glaeser, L. E., Hedi, K. D., Jose, S. A., and Andrei, S. (1992). Growth in cities. Journal of Political Economy, 100(6), 1126-1152.

Ha, S. T., Lo, M., and Wang, Y. C. (2016). Relationship between knowledge management and organisational performance: a test on SMEs in Malaysia. Procedia - Social and Behavioral Science, 224(1), 184-189.

Hamad, W. B. (2018). The role of ICT in knowledge management processes: a review. International Journal of Engineering Science and Computing, 8(3), 16373-16380.

Idoro, G. I. (2014). Foreword to conference book of proceedings. international conference of the international council for research and innovation in building and construction in developing countries (CIB). Lagos, Nigeria: University of Lagos and Heriot Watt University, Edinburgh, UK.

Jacobs, J. (1969). The economy of cities. New York: Vintage.

Jude, C. (2015). Technology spillovers from FDI. evidence on the intensity of different spillover channels. Paris: John Wiley and Sons Ltd.

Keller, W. (1996). Absorptive capacity: on the creation and acquisition of technology in development. Journal of Development Economics, 49(1), 199-227.

Koen, S., and Bartoldus, V. (2002). Foreign direct investment spillovers within and between sectors: evidence from Hungarian Data, Ghert University. Faculty of Economics and Business Discussion paper No. 157.

Marshall, A. (1890). Principles of economics. London: Macmillan.

Mason, G. (2018). Workforce skills at all levels boost innovation and productivity. London: LLAKES.

McDermott, G., and Corredoira, R. (2010). Network and composition, collaborative ties, and upgrading in emerging-market firms: Lessons from the Argentine autoparts sector. Journal of International Business Studies, 41(2), 308-329.

Merlevede, B., Schoors, K., and Spatareanu, M. (2014). FDI spillovers and time since foreign entry. World Development, 56(1), 108-126.

Muyendi, C. N., and Njuru, S. G. (2016). Determinant of foreign direct investment spillovers; kenya's domestic firms case. Journal of Business and Economic Policy, 3(3), 41-51.

Nasimi, M. H., Nasimi, S., Kasmaei, M. S., Kasmei, H. S., Basirian, F., and Musapour, H. (2013). Competitive advantage for organisations. Kuwait Chapter of Arabian Journal of Business and Management Review, 2(5), 1-10.

Omole, A. (2000). Surveying input to engineering projects: the need for professionalism. The Quantity Surveyor, 10-18.

Osabutey, E. L., and Jin, Z. (2016). Factors influencing technology and knowledge transfer: configurational recipes for Sub-Saharan Africa. Journal of Business Research, 69(11), 5390-5395.

Osabutey, E. L., Williams, K., and Debrah, Y. A. (2014). The potential for technology and knowledge transfers between foreign and local firms: a study of the construction industry in Ghana. Journal of World Business, 49(4), 560-571.

Ozturk, B., and Mrkaic, M. (2014). SMEs' access to finance in the Euro area: what helps or hampers? International Monetary Fund.

Porter, M. (1990). The competitive advantage of nations. London: Macmillan.

Romer, P. (1990). Endogenous technological change. Journal of Political, 98(5), 71-102.

Sorenson , O., Rivkin, J., and Fleming, L. (2006). Complexity, networks, and knowledge flow. Research Policy, 35(7), 994-1017.

Sorensson, R. (2010). Marshallian sources of growth and interdependent location of swedish firms and households (unpublished doctoral dissertation). Umea, Sweden: Department of Economics, Umea University.

Te Velde, D. W. (2019). Enhancing spillovers from foreign direct investment. Supporting Economic Transformation (SET).

Thanh, V. T., Cuong, T. T., Dung, B. V., and Chieu, T. D. (2011). Small and medium enterprises access to finance in Vietnam. Jakarta: ERIA Research Project Report.

Thompson, E. (2002). Clustering of foreign direct investment and enhanced technology transfer: Evidence from Hong Kong garment firms in China. World Development, 30(5), 873–889.

UNCTAD (2006). World investment report. Geneva: United Nations.

Yang, H., and Steensma, K. (2014). When do firms rely on their knowledge spillover recipients for guidance in exploring unfamiliar knowledge? Elsevier, 43(9), 1496–1507.

Zafar, N., Ishaq, S., Shoukat, S., and Rizwan, M. (2014). Determinants of Employee Motivation and its impact on Knowledge Transfer and Job Satisfaction. International Journal of Human Resource Studies, 4(3), 50-69.

Journal of Construction Project Management and Innovation, 12(1): 65-86, 2022
ISSN 2223-7852


# Causes of cost overruns on Zimbabwe's construction infrastructure projects

**Tirivavi Moyo[1] and Benviolent Chigara[2]**

[1&2]Department of Quantity Surveying, Nelson Mandela University, Port Elizabeth, South Africa

Email: tirivavi.moyo@mandela.ac.za; benviolent@gmail.com

## ABSTRACT

The cost performance of infrastructural projects has been problematic, especially in countries with fragile economies like Zimbabwe. However, interrogations of the causes of such cost overruns are scarce within the study area. This article reports on a study that sought to determine the causes of cost overruns on infrastructural construction projects and to establish statistically significant differences in ranking due to quantity surveyor designations. A survey on quantity surveyors from construction companies and quantity surveying consultancy firms in Zimbabwe was instituted and analysed through descriptive and inferential statistics. The most critical causes of cost overruns included currency exchange rate unpredictability, poor financial planning for the project, and an unstable economic climate. A statistically significant difference due to the designations was revealed in individual causes, indicating functional differentiation in determining preventative strategies. Ten components were revealed through factor analysis: excessive use of prime cost and provisional sums, unstable economic fundamentals, project complexity, and duration risks, amongst others. Inculcation of project management competencies, which include risk management, is recommended to resolve these challenges within the Zimbabwean construction industry. There is a need to innovate toward adequate planning for unstable economic climates and risk management. Only the perspectives of quantity surveyors were considered due to the exploratory nature of the study; however, their role in the cost and financial management of construction projects validated their participation in the study.

**Keywords:** Cost overrun, infrastructure, Quantity surveyors, developing countries

## 1. INTRODUCTION

Research on cost overruns on construction projects has been topical and contentious in developed and developing countries (Dada, 2014; Steininger, 2020). More so for developing countries where fragile economic structures exist (Durdyev, 2021), thus significantly contributing negatively to their developmental goals. While a plethora of studies on causes of cost overruns on construction projects may indicate enough has been done, the continued focus signifies the need for distinctive interrogations and determinations from an empirical survey. This approach is paramount as it enables the generation of specific interventions within the Zimbabwean construction industry. This need is paramount for Zimbabwe, where the economic fundamentals are untenable. For example, the Global competitiveness report (2013) ranked the quality of the country's infrastructure amongst the lowest 15% in the world. Further, a 10% contraction of Gross Domestic Product (GDP) in 2020 and a negative projection for 2021, an inflation rate ranging around 53% in the last quarter of 2021, and an unstable foreign currency exchange rate (African development bank group, 2021), are all detrimental to the construction industry's performance. The less than 1% contribution of the construction industry to the GDP (Zimbabwe National Statistics Agency, 2020) may seem insignificant. However, the thrust of the Zimbabwe government towards financing the housing, roads and dam infrastructural projects from the GDP (The Zimbabwe infrastructure development programme, 2021) supports the focus on remedying cost overruns caused on such projects. This, theoretically and not empirically, potentially explains the general cost and time overruns on infrastructural construction projects (Chigara and Moyo, 2014; Moyo, Crafford and Emuze, 2021) and more complex and related challenges of productivity, profitability, and performance (Mhlanga, 2017; Mhlanga, 2018). Although time overruns are equally important, cost overruns have taken centre stage in many studies, especially for infrastructural projects. Thus, they are the focus of this study.

Despite cost overruns being topical, research on this aspect in the study area is scarce. Hence, the objectives of this study are two-fold. First, this study examines the important causes of cost overruns on infrastructural projects in Zimbabwe. Various authors support contextual approaches to causes of cost overruns as they enable appropriate responses within the study areas (Amadi and Higham, 2017; Akinradewo et al., 2019; Mahmud et al., 2021). Second, the statistically significant differences between the views of consultant and contractor's quantity surveyors are examined. While a significant number of studies (Park and Papadopoulou, 2012; Ahiaga-Dagbui and Smith, 2014; Adam et al., 2017; El- Maaty, 2017; Lu et al., 2017; Habibi and Kermanshachi, 2018) considered insights from various construction professionals, this study sought perceptions from the most proficient professional on cost and financial management aspects of construction projects (Royal Institute of Chartered Surveyors, 2018). Quantity surveyors, also known as construction economists or cost managers, are critical for the financial management of construction projects (Dada and Jagboro, 2012; Shayan et al., 2019) hence they are best to participate in this exploratory study. Consequently, this study considers the consultants' and contractors' quantity surveyors within the designated demography. The role and responsibility differences among the respective quantity surveyors that work for consultants' and contractors' organisations indicate potential differences in insights on the causes of cost overruns on infrastructural projects (Ramus et al., 2008). Hence, the importance of the causes of the cost overruns is likely dependent on designation factors.

The next section of the article reports on the cost performance of infrastructural projects, which includes a review of the causes of cost overruns from previous studies. Then, the research method utilised to address the research questions is clarified, and the findings are delineated. Lastly, the conclusions on the causes and remedies of cost overruns are stated together with the study's recommendations and limitations.

## 2. COST PERFORMANCE OF INFRASTRUCTURAL PROJECTS

As a key performance criterion, the cost has been a prominent definition of project success (Asiedu and Adaku, 2020). Cost overruns have been borne in technical, economical, psychological and political issues (Steinger et al., 2021). Cost overruns are defined as excesses beyond the set budget or cost of a construction project (Amoatey et al., 2015). Cost overruns include all loss and expense claims and changes in scope due to project conditions (Oyewobi et al., 2016). Uncertainties in the construction industry environment contribute to difficulties in the management of costs and lead to cost overruns (Olatunde and Alao, 2017). The cost overrun conundrum has been a popular topic in construction projects worldwide, with the effective use of cost control techniques being significant (Oyegoke et al., 2021), albeit to varying extents.

Cost performance is critical to the success or failure of infrastructural construction projects (Olatunde and Alao, 2017). Notwithstanding the complexity of infrastructural projects increasing, as citizens seek healthy and sustainable environments (Steinger et al., 2021, Afzal et al. (2021) assert that cost overrun issues have been common due to the complex and dynamic nature of infrastructural construction projects. In addition, the risk information uncertainty and the risk network's complexity have been identified as the root cause of cost overruns (Afzal et al., 2021). Although project success has been dependent on controlling costs (Oyegoke et al., 2021), cost overrun factors have been numerous and emanate from various sources.

## 2.1 Causes of cost overruns from previous studies

Dada (2014) revealed that cost overruns are significantly dependent on the nature of project team relationships in Nigeria. However, no dependence on procurement methods exists. Contrary to the findings, the implication of project team relationships within procurement methods is difficult to ignore, both being significant to the extent of cost overruns. However, Dada (2014) determined client-contractor relationships to have the most significant influence on explaining cost overruns on construction projects, as supported by Park and Papadopoulou (2012) and Ahiaga-Dagbui and Smith (2014). Sambasivan et al. (2017) determined consultant-related, material-related, and dispute-related issues as explaining cost overruns on construction projects. Akinradewo et al. (2019) revealed significant factors related to owner/consultant, environmental, political, economic, bidding, construction, project, contractor, design, resources, technical/managerial, and legal. Afzal et al. (2020) classified the cost risk factors into dimensions of the engineering design process, construction management practices, construction safety standards, geographical natural hazards, and domestic social and economic problems. Oyegoke et al. (2021) categorise the cost overruns factors into nine (9) broader themes of price and cost, delay and extension of time, project management, design, construction, payments, contractor-specific factors, consultants' specific factors, and force majeure.

As evidenced by the studies above, the plethora of categorisations of causes of cost overruns suggests that contextual consideration is paramount. Therefore, this study considered the causes of cost overruns as contractor-related, client and consultant-related, and external and project-related factors. This is supported by the study by Dada (2014), which determined client-contractor relationships as having the most significant influence on explaining cost overruns. Hence, Table 1 summarises the categories selected for this study. In addition, the actual causes were selected from previous similar studies, especially within developing countries. Therefore, justification of the causes is reviewed hereafter, together with the shortcomings of previous similar studies. This study will address, as it seeks to determine causes of cost overruns on infrastructural projects and proffer mitigatory measures.

**Table 1:** Causes of cost overruns from previous studies

| No. | Causes | Sources |
|---|---|---|
| | **Contractor related** | |
| CC1 | Poor material planning | Enshassi et al. (2009), Adam et al. (2017), El-Maaty et al. (2017), Famiyeh et al. (2017), Habibi and Kermanshachi (2018), Akinradewo et al. (2019), Asiedu and Ameyaw (2021) |

| | | |
|---|---|---|
| CC2 | Poor plant and machinery planning | Enshassi et al., (2009), Adam et al., (2017), El-Maaty et al., (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019) |
| CC3 | Poor labour planning | Enshassi et al. (2009), Park and Papadopoulou (2012), Adam et al. (2017), El-Maaty et al. (2017), Famiyeh et al. (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019) |
| CC4 | Shortage of adequate plant and equipment | Habibi and Kermanshachi (2018) |
| CC5 | Poor organisation structure | Ahiaga-Dagbui and Smith (2014), Enshassi et al., (2009), Lu et al., (2017), Akinradewo et al., (2019) |
| CC6 | Poor process procedures | Enshassi et al. (2009), Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), El-Maaty et al. (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019) |
| CC7 | Poor site management | Enshassi et al. (2009), Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Lu et al. (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019) |
| CC8 | Poor cost monitoring and control by contractors | Enshassi et al. (2009), Ahiaga-Dagbui and Smith (2014), El-Maaty et al. (2017), Famiyeh et al. (2017), Lu et al. (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019) |
| **Client and Consultant related** | | |
| CC9 | Poor budget estimation of the project cost by consultants | Enshassi et al. (2009), Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Adam et al. (2017), Famiyeh et al. (2017) |
| CC10 | Inadequate design specifications | Ahiaga-Dagbui and Smith (2014), Akinradewo et al. (2019), Lu et al. (2017), Durdyev (2021) |
| CC11 | Lack of communication between clients and consultants | Park and Papadopoulou (2012) Ahiaga-Dagbui and Smith (2014) Adam et al., (2017) El-Maaty et al., (2017), Famiyeh et al., (2017), Lu et al., (2017), Habibi and Kermanshachi (2018), Asiedu and Ameyaw (2021), Durdyev (2021) |
| CC12 | Lack of communication and coordination between consultants | Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Adam et al., (2017), El-Maaty et al., (2017), Lu et al., (2017), Habibi and Kermanshachi (2018), Durdyev (2021) |
| CC13 | Deficiencies with procurement methods | Park and Papadopoulou (2012), Akinradewo et al. (2019), Asiedu and Ameyaw (2021) |
| CC14 | Client initiated changes | Enshassi et al. (2009), Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Famiyeh et al. (2017) Lu et al. (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019) |
| CC15 | Slow decision-making by the project team | Enshassi et al., (2009), Adam et al., (2017), Famiyeh et al., (2017) Lu et al., (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019) |
| CC16 | Delays between tender and contract award date | Enshassi et al., (2009), El-Maaty et al., (2017), Famiyeh et al., (2017), Akinradewo et al., (2019) Asiedu and Ameyaw (2021) |
| CC17 | Delays and uncertainties surrounding payment of work done | Enshassi et al. (2009), Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Famiyeh et al. (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019), Asiedu and Ameyaw (2021) |
| CC18 | Lack of frequent and effective supervision by consultants | Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Adam et al. (2017), Famiyeh et al. (2017), Asiedu and Ameyaw (2021) |
| CC19 | Deliberate underestimation of the initial project cost | Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Adam et al. (2017), Famiyeh et al. (2017), Habibi and |

| | | |
|---|---|---|
| | | Kermanshachi (2018), Akinradewo et al., (2019) Asiedu and Ameyaw (2021), Durdyev (2021) |
| CC20 | Poor financial planning for the project | Enshassi et al., (2009), Adam et al., (2017), El-Maaty et al., (2017), Famiyeh et al., (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019), Durdyev (2021) |
| CC21 | Errors and discrepancies in the contract documents | Enshassi et al. (2009), Ahiaga-Dagbui and Smith (2014), Habibi and Kermanshachi (2018), Asiedu and Ameyaw (2021) |
| **External and project-related factors** | | |
| CC22 | Harsh weather conditions | Enshassi et al. (2009), Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Adam et al. (2017), Famiyeh et al. (2017), Habibi and Kermanshachi (2018), Asiedu and Ameyaw (2021), Durdyev (2021) |
| CC23 | Lack of enforcement of contract provisions by all parties | Enshassi et al. (2009), Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Famiyeh et al. (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019), Asiedu and Ameyaw (2021), Durdyev (2021) |
| CC24 | Unforeseen ground conditions | Enshassi et al. (2009), Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Habibi and Kermanshachi (2018), Akinradewo et al. (2019), Asiedu and Ameyaw (2021), Durdyev (2021) |
| CC25 | Poor calibre of contractors selected | Enshassi et al., (2009), El- Maaty et al., (2017), Lu et al., (2017), Akinradewo et al., (2019) Asiedu and Ameyaw (2021) |
| CC26 | Collusion between consultant and contractor | Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Akinradewo et al. (2019), Asiedu and Ameyaw (2021) |
| CC27 | Excessive bribery and cronyism | Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), Akinradewo et al. (2019), Asiedu and Ameyaw (2021) |
| CC28 | Project complexity | Ahiaga-Dagbui and Smith (2014), Lu et al. (2017), Habibi and Kermanshachi (2018) |
| CC29 | Long project duration | Ahiaga-Dagbui and Smith (2014), Habibi and Kermanshachi (2018), Akinradewo et al. (2019) |
| CC30 | Currency exchange rate unpredictability | Enshassi et al. (2009), Park and Papadopoulou (2012), Habibi and Kermanshachi (2018), Akinradewo et al. (2019) |
| CC31 | Unstable economic climate | Enshassi et al., (2009), Habibi and Kermanshachi (2018), Akinradewo et al., (2019) |
| CC32 | Excessive use of prime cost and provisional sums | Famiyeh et al., (2017), Asiedu and Ameyaw (2021) |
| CC33 | Excessive increase in material and labour prices | Enshassi et al. (2009), Park and Papadopoulou (2012), Ahiaga-Dagbui and Smith (2014), El-Maaty et al. (2017, Famiyeh et al. (2017), Habibi and Kermanshachi (2018), Akinradewo et al., (2019), Asiedu and Ameyaw (2021), Durdyev (2021) |

Consistent with Table 1, Shehu et al. (2014) reported on the most critical factors that affected delays. These were cost-related and included cash flow problems faced by the contractor and difficulties in financing the project by the contractor. The cumulative results showed that all the other professionals (Architects, Engineers and Project managers) agreed with Quantity surveyors on these critical factors. Although Amoatey and Ankrah (2017) reported on a study on the most critical causes of road construction delays, the nature of the causes is cost and finance-related. These include delays in finance and payment of completed work by owners, changes in scope by the owner during construction, inadequate contractor experience, and delays in furnishing and delivering the site to the contractor. These findings are consistent with studies on causes of cost overruns by Enshassi et al. (2009) and Habibi and Kermanshachi (2018). Olatunde and Alao (2017) revealed that most public and private universities in the Osun state of Nigeria were completed beyond the estimated costs.

Further, suggested interventions of detailed client briefs, precision in design development, adequate cost engineering by quantity surveyors, and improved integrity and professionalism of contractors were proffered. However, Akinradewo et al. (2019) also determined additional cost aspects and poor financial control on sites as the most causative factors for cost overruns on construction projects in South-Western Nigeria. Significantly, there was consensus from the construction professionals (Architects, Builders, Engineers, Project Managers and Quantity Surveyors) on the causative factors. However, the plethora and overlap of the factors make it difficult to institute responses to these causes, although not impossible.

Afzal et al. (2020) revealed that poor design issues and material price increases increased the risk of cost overruns on transit projects in China. However, experts' perceptions present non-holistic and subjective response bias, although developing a cost-risk contingency would aid effective cost planning (Afzal et al., 2020). Similarly, Aje et al. (2017) identified design and documentation issues and ineffective financial management by construction stakeholders as two of the most prevalent causes of cost overruns on construction projects. However, in their study, external factors were found insignificant in causing cost overruns. Olatunji et al. (2018) also revealed a significant correlation between cost overruns and material price fluctuations. The authors suggested price risk mitigation through rewarding efficiency and intelligence.

Project complexity and unforeseen ground conditions are significant for accurately assessing contingency sum allowances, justifying a departure from the mainly utilised traditional percentage assessment method even for public sector infrastructural projects (Lam and Siwingwa, 2017). Thus, predictive models for contingency sums are supported for enhancing project cost performance. Generally, the implementation of risk management is pertinent in contingency sum estimation. For example, Amadi and Higham (2017) empirically exposed the contribution of geotechnical factors to cost overruns on highway projects in Nigeria. Consequently, effective geotechnical investigations at pre-contract stages were supported to exponentially reduce the extent of cost overruns on such infrastructural projects.

Cost performance has been significantly affected by change orders on construction projects during the construction phase (Shrestha et al., 2019). Further, probability curves were suggested as a way of predicting cost growth through the determination of change orders. Effective change management systems were extended. Oyewobi et al. (2016) also determined increases in construction costs as the most frequent effect of variations.

An analysis of the reviewed causes of cost overruns and contextual singularities of the study area was important in determining the methodology for this study, as explained in the next section.

## 3. METHODOLOGY

This research is part of a broader study on issues affecting Zimbabwe's construction industry. Hence, certain aspects of the methodology are similar to articles published in other journals. A survey research strategy was utilised in this quantitative study as it enabled interpretation and generalisability (Saunders et al., 2016). A questionnaire survey, as supported by Famiyeh et al. (2017) and Asiedu and Ameyaw (2021), was initially undertaken to collect quantitative data on the causes of cost overruns from both consultants' and contractors' quantity surveyors. Consequently, remedies were derived from the revealed important causes of cost overruns. The exploratory nature of this study limited respondents to quantity surveyors due to them having the most robust understanding of cost and financial issues on construction projects. All eighty-three (83) construction companies resident in Harare and Bulawayo and listed in the list of companies of the Construction Industry Federation of Zimbabwe (CIFOZ) (2021) were included in the contractors' quantity surveyor selection. According to the CIFOZ list, more than 90% of the construction companies in Zimbabwe are found in the selected geographical areas. Consultant quantity surveyors in all twenty-two (22) quantity surveying firms in Zimbabwe were also selected for the study. For the quantitative inquiry, a web-based questionnaire was instituted, and it comprised two sections. The first section requested demographic information on gender, designation, educational levels and experience, while the second section required the respondents to rate the importance of causes of cost overruns on infrastructural construction projects where 1- not important, 2–slightly important, 3- somewhat important, 4- important and 5- very important. The relative importance index (RII) was utilised to evaluate univariate importance. Importance intervals, as modified by Perera et al. (2007), as follows: 'not important' < 0.2; 0.2< 'of little importance' ≤ 0.4; 0.4< 'somewhat important' ≤ 0.6; 0.6< 'important' ≤ 0.8; 0.8< 'very important' ≤ 1. From this evaluation scale, importance was regarded from RII of ≥ 0.6.

The Statistical Package for Social Science (SPSS) version 24 (with 95% confidence in the results) was used to aid descriptive and inferential statistical analysis (Field, 2014). An excellent reliability of 0.933 was computed using the Cronbach alpha reliability test, which showed that the questionnaire provided stable and consistent results (Taherdoost, 2016). Factor analysis reduced the variables by assembling common variables into descriptive categories (Yong and Pearce, 2013), and it was utilised to reveal the significant interrelated causes of cost overruns. The resultant latent variables' occurrence is hidden but represents the accurate measure of the variables (Santos et al., 2019). The validity of data for conducting factor analysis was confirmed by the Kaiser-Meyer-Olkin (KMO) test, where an acceptable measure of 0.623 was obtained as it was > 0.5 (George and Mallery, 2003; Ather and Balasundaram, 2009). A significant Bartlett's test for sphericity value of 0.000, which was < 0.05, indicated that the correlation matrix was not random (Watkins, 2018). Significant components with eigenvalues ≥ 1, were extracted using the principal component analysis with varimax rotation (Kaiser, 1958). Eigenvalues measure the variance in all variables attributable to that component or factor, and those with values < 1 are discarded (Ather and Balasundaram, 2009). Varimax rotation is strategic in maximising variance for each factor by enhancing the high loadings and lowering the low loadings (Benson and Nasser, 1998). Acceptable loadings ≥ 0.4 were considered stable for utilisation (Guadagnoli and Velicer, 1988). The descriptive categories of components' titles were derived from the constituents' variables (Lu et al., 2017; Asiedu and Ameyaw, 2021; Yap et al., 2021) instead of utilising the variable with the highest factor model (Ather and Balasundaram, 2009).

Since the data were not normally distributed due to a sig. Shapiro-Wilk test value of 0.032 for samples more than 50, which is less than 0.05 (Ghasemi and Zahediasl, 2012), the use of non-parametric tests for testing significant differences due to demographic variables are supported. Blumberg, Cooper and Schindler (2008) define the Mann-Whitney U test as a test comparing the central tendency of two independent samples, in this case, designation. The statistical significance level for all tests is based on a standard value of $p < 0.05$.

## 4. RESULTS AND DISCUSSION

This section reports on the profile of respondents as well as results and discussion on the causes of cost overruns on infrastructural construction projects.

### 4.1 Profile of respondents

The response rate for participation was a combined 48.6%, represented by 51 respondents (14 out of 22 consultants' quantity surveyors and 37 out of 83 contractors' quantity surveyors) from a population size of 105. This was satisfactory and acceptable as it complies with Moser and Kalton (1979)'s return rate lower limit of 30% for validity. Hence, the validity of the study is supported by this response rate. The profile of respondents, as shown in Table 2, represents the construction industry in Zimbabwe.

**Table 2:** Demographics of respondents

| Description | Total | Proportion (%) |
|---|---|---|
| *Gender* | | |
| Male | 44 | 86 |
| Female | 7 | 14 |
| *Designation* | | |
| Contractor's Quantity surveyor | 37 | 72 |
| Consultant's Quantity surveyor | 14 | 28 |
| *Educational Level* | | |
| Diploma | 17 | 33 |
| Degree | 19 | 37 |
| MSc | 15 | 30 |
| *Experience* | | |
| 0 – 5 Years | 19 | 37 |
| 6-10 Years | 15 | 30 |
| 11-15 Years | 9 | 18 |
| Above 15 Years | 8 | 15 |

Cumulatively, all the demographic variables are competently constituted to allow for statistical analysis and validity of the study.

### 4.2 Causes of cost overruns

As shown in Table 3, respondents submitted their insights on important causes of cost overruns on infrastructure projects in Zimbabwe. The overall results show that the univariate causes of Unforeseen ground conditions (RII=0.592) and Harsh weather conditions (0.514) were not important, as their RII was < 0.6. Seven of the causes were very important, with Currency exchange rate unpredictability (RII= 0.894), Poor financial planning for the project (RII=0.855), and Unstable economic climate (RII=0.851) being the most important. These are critical external and project-related causes that require national policy intervention and enhancing quantity surveying functions of financial planning. The economic structure of some developing countries, as alluded to by Enshassi et al. (2009) and Akinradewo et al. (2019), is characterised by such economic shocks, and responses should include the conducting of construction business in more stable currencies. Innovation is required in dealing with financial planning, where vast uncertainties hamper forecasting. Key project management competencies, including risk management, can go a long way in preparing construction professionals for working in such conditions. Hence, there is a need to have these skills developed and incorporated into their continuous professional development. Table 3 also shows the differences in insights by consultants and contractors' quantity surveyors. The Mann-Whitney results show* significant differences where the value is ≤ 0.05.

**Table 3:** Ranking of causes of cost overruns

| | **Causes of cost overruns** | **Overall** | | **Consultants' Quantity Surveyor** | | **Contractors' Quantity Surveyor** | | **Mann Whitney results** |
|---|---|---|---|---|---|---|---|---|
| | | RII | Rank | RII | Rank | RII | Rank | Sig |
| CC30 | Currency exchange rate unpredictability | 0.894 | 1 | 0.943 | 1 | 0.876 | 1 | 0.138 |
| CC20 | Poor financial planning for the project | 0.855 | 2 | 0.857 | 11 | 0.854 | 2 | 0.849 |
| CC31 | Unstable economic climate | 0.851 | 3 | 0.943 | 1 | 0.816 | 6 | 0.078 |
| CC11 | Lack of communication between clients and consultants | 0.843 | 4 | 0.842 | 16 | 0.843 | 3 | 0.772 |
| CC33 | Excessive increase material and labour prices | 0.843 | 4 | 0.886 | 5 | 0.827 | 4 | 0.206 |
| CC8 | Poor cost monitoring and control by contractors | 0.839 | 6 | 0.886 | 5 | 0.822 | 5 | 0.187 |
| CC27 | Excessive bribery and cronyism | 0.808 | 7 | 0.829 | 17 | 0.800 | 8 | 0.539 |
| CC9 | Poor budget estimation of the project cost | 0.796 | 8 | 0.871 | 9 | 0.768 | 10 | 0.071 |
| CC14 | Client initiated change orders | 0.792 | 9 | 0.757 | 29 | 0.805 | 7 | 0.594 |
| CC15 | Slow decision-making by the project team | 0.792 | 9 | 0.771 | 25 | 0.800 | 8 | 0.911 |
| CC10 | Inadequate design specs | 0.788 | 11 | 0.843 | 15 | 0.768 | 10 | 0.700 |
| CC4 | Shortage of adequate plant and equipment | 0.780 | 12 | 0.857 | 11 | 0.751 | 12 | 0.126 |
| CC13 | Deficiencies with procurement methods | 0.773 | 13 | 0.900 | 3 | 0.724 | 19 | 0.002* |
| CC1 | Poor material planning | 0.772 | 14 | 0.886 | 5 | 0.730 | 17 | 0.010* |
| CC29 | Long project duration | 0.761 | 15 | 0.800 | 21 | 0.746 | 13 | 0.335 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CC17 | Delays and uncertainties surrounding payment of work done | 0.765 | 15 | 0.814 | 18 | 0.746 | 13 | 0.160 |
| CC7 | Poor site management | 0.761 | 17 | 0.871 | 9 | 0.719 | 20 | 0.014* |
| CC19 | Deliberate underestimation of the initial project cost | 0.761 | 17 | 0.814 | 18 | 0.740 | 16 | 0.371 |
| CC2 | Poor plant and machinery planning | 0.760 | 19 | 0.814 | 18 | 0.741 | 15 | 0.177 |
| CC3 | Poor labour planning | 0.749 | 20 | 0.900 | 3 | 0.692 | 24 | 0.000* |
| CC16 | Delays between tender and contract award date | 0.745 | 21 | 0.786 | 24 | 0.730 | 17 | 0.190 |
| CC25 | The poor calibre of contractors | 0.745 | 21 | 0.857 | 11 | 0.703 | 22 | 0.012* |
| CC32 | Excessive use of prime cost and provisional sums | 0.737 | 23 | 0.857 | 11 | 0.692 | 24 | 0.006* |
| CC5 | Poor organisation structure | 0.729 | 24 | 0.886 | 5 | 0.670 | 29 | 0.003* |
| CC12 | Lack of coordination and communication between the consultants | 0.725 | 25 | 0.800 | 21 | 0.697 | 23 | 0.045* |
| CC21 | Errors and discrepancies in the contract document | 0.725 | 25 | 0.771 | 25 | 0.708 | 21 | 0.229 |
| CC6 | Poor process procedures | 0.714 | 27 | 0.800 | 21 | 0.681 | 27 | 0.040* |
| CC18 | Lack of frequent and effective supervision by consultants | 0.710 | 28 | 0.771 | 25 | 0.686 | 26 | 0.243 |
| CC28 | Project complexity | 0.698 | 29 | 0.743 | 30 | 0.681 | 27 | 0.299 |
| CC23 | Lack of enforcement of contract provisions by all parties | 0.694 | 30 | 0.771 | 26 | 0.665 | 30 | 0.073 |
| CC26 | Collusion between consultants and contractors | 0.671 | 31 | 0.686 | 31 | 0.665 | 30 | 0.793 |
| CC24 | Unforeseen ground conditions | 0.592 | 32 | 0.557 | 33 | 0.605 | 32 | 0.514 |
| CC22 | Harsh weather conditions | 0.514 | 33 | 0.586 | 32 | 0.486 | 33 | 0.229 |

*Significant differences ≤ 0.05

The individual causes of cost overruns, as shown in Table 4, were subsequently analysed concerning their statistically significant differences.

**Table 4:** Summary of Mann-Whitney U test results on designations

| Causes of cost overruns | Sig. | Designation means ranks | |
|---|---|---|---|
| | | Consultant's quantity surveyor | Contractor's quantity surveyor |
| CC1 Poor material planning | 0.010 | 34.29 | 22.86 |
| CC3 Poor labour planning | 0.000 | 37.00 | 21.84 |
| CC5 Poor organisation structure | 0.003 | 35.57 | 22.38 |
| CC6 Poor process procedures | 0.040 | 32.50 | 23.54 |
| CC7 Poor site management | 0.014 | 33.96 | 22.99 |
| CC12 Lack of coordination and communication between the consultants | 0.045 | 32.50 | 23.54 |
| CC13 Deficiencies with procurement methods | 0.002 | 36.04 | 22.20 |
| CC25 The poor calibre of contractors | 0.012 | 34.14 | 22.92 |
| CC32 Excessive use of prime cost and provisional sums | 0.006 | 34.86 | 22.65 |

For all the individual causes of cost overruns with significant differences, as shown in Table 4, the consultant's quantity surveyors ranked them higher than the contractor's quantity surveyor. While both designations acknowledged their importance, contractors' quantity surveyors ranked them as less important than their consultants' quantity surveyors. These causes speak to insufficiencies within construction companies in undertaking appropriate planning for and managing their projects, as Enshassi et al. (2009) highlighted. While it is inevitable that these causes lead to the construction companies incurring cost overruns, their contribution to the infrastructural project cost overruns needs to be clarified.

Potentially the client faces indirect and direct cost overruns from the lack of planning and mismanagement of construction companies as alluded to by the causes due to Poor material planning, Poor labour planning, Poor organisation structure, Poor process procedures, and Poor site management. The causes of cost overruns that are client and consultant-related include Deficiencies with procurement methods and Lack of coordination and communication between the consultants. While both parties acknowledge the deficiencies of procurement methods as a cause of cost overruns, as supported by Park and Papadopoulou (2012), consultants play a prominent role in its selection and implementation. For emphasis, procurement methods within the public sector are regulated but are not immune to interrogation. The Lack of coordination and communication between consultants is also a cause for concern (Dada, 2014). This points to a general need for more technological advancement within the coordination and communication of consultants. Introducing such advancements as building information modelling is highly recommended to improve the synergy amongst consultants.

The causes of cost overruns that are external and project-related include Excessive use of prime cost and provisional sums and the poor calibre of contractors. The excessive use of prime cost and provisional sums has been perceived, especially by consultants' quantity surveyors, as being highly contributory to cost overruns, which is supported by El-Maaty et al., (2017). Having large infrastructural projects being initiated with substantial work items being allocated under prime cost and provisional sums has been expected. However, these allocations have contributed to cost overruns. Such a large allocation for unknown costs needs to be rectified by allowing for completion of all designs and procurement of sub-contractors prior to tendering and commencement of works. This gives more confidence to the estimated construction costs, and the client faces a lesser risk of budget overrun. The poor calibre of contractors selected for project works is also of concern (Lu et al., 2017). Although consultants' quantity surveyors view this as a significant cause of cost overruns, they contribute to this problem through their evaluation and recommendation of tenders. However, their susceptibility to cause any overruns may be reduced to other factors.

### 4.3 Relationships within the causes of cost overruns

Further to the univariate analysis, a multivariate analysis was undertaken to expose any relationships within the causes of cost overruns. The analysis revealed ten (10) groups of causes of cost overruns with an eigenvalue of $\geq 1$, which explained 79.059% of the total variance with factor loadings ranging from 0.843 to 0.430, as shown in Table 5. The titles of each component were derived from the causes of cost overruns (Ather and Balasundaram, 2009).

**Table 5:** Factor analysis results

| Item | Causes of cost overruns | Component | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| 1 | *Project on-site and pre-contract planning inadequacies* | | | | | | | | | | |
| | CC1 Poor material planning | 0.795 | | | | | | | | | |
| | CC2 Poor plant and machinery planning | 0.766 | | | | | | | | | |
| | CC3 Poor labour planning | 0.733 | | | | | | | | | |
| | CC4 Shortage of adequate plant and equipment | 0.667 | | | | | | | | | |
| | CC10 Inadequate design specifications | 0.562 | | | | | | | | | |
| | CC5 Poor organisation structure | 0.561 | | | | | | | | | |
| | CC9 Poor budget estimation of the project cost | 0.523 | | | | | | | | | |
| | CC24 Unforeseen ground conditions | 0.430 | | | | | | | | | |
| 2 | *Poor organisational, communication and procurement structures* | | | | | | | | | | |
| | CC6 Poor process procedures | | 0.795 | | | | | | | | |
| | CC7 Poor site management | | 0.743 | | | | | | | | |
| | CC25 Poor calibre of contractors | | 0.720 | | | | | | | | |
| | CC11 Lack of communication between clients and consultants | | 0.690 | | | | | | | | |
| | CC12 Lack of communication and coordination between consultants | | 0.545 | | | | | | | | |
| | CC13 Deficiencies with procurement methods | | 0.522 | | | | | | | | |
| 3 | *Poor project change management and initiation and inclement weather* | | | | | | | | | | |
| | CC14 Client initiated changes | | | 0.843 | | | | | | | |
| | CC15 Slow decision-making by the project team | | | 0.770 | | | | | | | |
| | CC16 Delays between tender and contract award date | | | 0.625 | | | | | | | |
| | CC22 Harsh weather conditions | | | 0.440 | | | | | | | |
| 4 | *Inadequate contractual management* | | | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CC17 Delays and uncertainties surrounding payment of work done | | | | 0.838 | | | | | | |
| | CC23 Lack of enforcement of contract provisions by all parties | | | | 0.733 | | | | | | |
| | CC26 Collusion between consultant and contractor | | | | 0.519 | | | | | | |
| 5 | *Inadequate consultant supervision and corruption* | | | | | | | | | | |
| | CC18 Lack of frequent and effective supervision by consultants | | | | | 0.769 | | | | | |
| | CC27 Excessive bribery and cronyism | | | | | 0.735 | | | | | |
| 6 | *Poor cost, financial and contractual professionalism* | | | | | | | | | | |
| | CC19 Deliberate underestimation of the initial project cost | | | | | | 0.804 | | | | |
| | CC20 Poor financial planning | | | | | | 0.497 | | | | |
| | CC21 Errors and discrepancies in the contract documents | | | | | | 0.477 | | | | |
| 7 | *Poor cost planning, monitoring and control* | | | | | | | | | | |
| | CC33 Excessive increase in material and labour prices | | | | | | | 0.735 | | | |
| | CC8 Poor cost monitoring and control by contractors | | | | | | | 0.521 | | | |
| 8 | *Project complexity and duration risks* | | | | | | | | | | |
| | CC28 Project complexity | | | | | | | | 0.834 | | |
| | CC29 Long project duration | | | | | | | | 0.671 | | |
| 9 | *Unstable economic fundamentals* | | | | | | | | | | |
| | CC30 Currency exchange rate unpredictability | | | | | | | | | 0.744 | |
| | CC31 Unstable economic climate | | | | | | | | | 0.501 | |
| 10 | *CC32 Excessive use of prime cost and provisional sums* | | | | | | | | | | 0.517 |
| | *Eigenvalue* | 11.305 | 2.199 | 2.083 | 1.843 | 1.789 | 1.669 | 1.480 | 1.361 | 1.296 | 1.063 |
| | *The proportion of variance (%)* | 34.257 | 6.663 | 6.312 | 5.586 | 5.423 | 5.058 | 4.485 | 4.125 | 3.927 | 3.222 |
| | *Cumulative variance (%)* | 34.257 | 40.919 | 47.232 | 52.818 | 58.240 | 63.299 | 67.784 | 71.909 | 75.837 | 79.059 |
| | Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 40 iterations. | | | | | | | | | | |

Each group of causes of cost overruns is discussed hereafter.

*Component 1- Project on-site and pre-contract planning inadequacies*

The first group of interrelated causes of cost overruns, as shown in Table 5, was named 'Project on-site and pre-contract planning inadequacies' and accounted for 11.306 eigenvalues and a variance of 34.257%. This group consists of contractor-related, client, consultant, and external and project-related causes of cost overruns. Of the contractor-related causes, the study revealed that the emphasis is on the need for proper planning and application of organisational structures by construction companies in dealing with material, labour and plant and equipment requirements of infrastructural projects as supported by Habibi and Kermanshachi (2018) and Akinradewo et al., (2019). Successful cost performance is reliant on sound management practices in these aspects. Achieving this also requires the site management team to be well-trained in construction management. However, this is a potential challenge, as construction organisations need to coordinate better and train construction industry professionals. Management programmes instituted by professional bodies are necessary for the industry to be improved. Establishing material labour, plant and equipment baselines, and execution strategies are paramount in any planning activity. Efficient cost performance is only achieved once these aspects have been sufficiently resolved. Client and consultant-related causes of cost overruns that include Inadequate design specifications and Poor budget estimation of the project cost, as suggested by Olatunde and Alao (2017), relate to competency inadequacies of construction professionals. Architectural, Engineering and Quantity surveying professionals ensure that all design specifications are complete and accurate (Afzal et al., 2020). There is strong advocacy for enhanced financial literacy and management for all construction professionals, as more often than not, the cost is the "bottom line" for the construction of infrastructural projects. In addition, incentivised professional contracts that include penalties for any shortcomings of construction consultants may push for improved competency. Unforeseen ground conditions have been ever-present in the construction industry (Amadi and Higham, 2017; Lam and Siwingwa, 2017). While this external factor is unforeseen, comprehensive risk management can be instituted to reduce the effects of this aspect on the cost performance of the construction of infrastructural projects.

*Component 2- Poor organisational, communication, and procurement arrangements*

The second group of interrelated causes of cost overruns, as shown in Table 5, was named 'Poor organisational, communication and procurement arrangements' and accounted for 2.199 eigenvalues and a variance of 6.663%. This group consists of contractor-related, client, consultant, and external and project-related causes of cost overruns. Poor process procedures and Poor site management are contractor-related causes of cost overruns that are borne on-site within construction companies. As highlighted in the first component, construction companies have management challenges, and they need to be well-trained to efficiently and effectively manage their construction sites (Enshassi et al., 2009). Waste minimisation and value maximisation are pertinent and are supported by lean construction implementation on construction sites. Effective communication among the project team, between clients and consultants and consultants, has seemingly deteriorated, which was considered a significant factor by Dada (2014). This could be due to several factors, including cultural, technological and technical differences. Thus, improvements should be encapsulated in modern forms of communication. Besides technical communication being pertinent, other types of communication between clients and consultants need to be improved. Consultants should have the flexibility to communicate effectively to various audiences and this can be inculcated through stakeholder analysis and project communication management. The Poor calibre of contractors, as supported by Olatunde and Alao (2017), and the Deficiences of procurement methods (Asiedu and Ameyaw, 2021) are the two external and project-related causes of cost overruns in the group. Brain drains and lack of technological advances within the construction companies have hampered any positive development of these firms. The quality of the construction companies needs to be considered from a policy context. Also, construction companies need concessions and considered policy allowances that facilitate their growth. The absence of all these targeted interventions has perpetuated the perception of the poor calibre of construction companies. Attempts to motivate partnerships with international entities have yet to bring about the expected benefits. Hence, the capacitation of construction firms is paramount to resolving the challenges. The existent procurement methods have been perceived to be deficient in ensuring adequate cost performance of infrastructural construction projects. The treasury and privately funded projects have been procured under specific and regulated methods. Any challenges should have been well documented, and efforts to remedy them duly implemented. However, construction professionals' general need for proactiveness has contributed to the challenge. The possibility of exploiting the shortcomings of the procurement methods must be addressed. The rampant corruption in the construction industry is a testimony to a perceived lack of proactiveness in resolving procurement deficiencies.

*Component 3- Poor project change and initiation management and inclement weather*

The third group of interrelated causes of cost overruns, as shown in Table 5, was named 'Poor project change management and initiation and inclement weather and accounted for 2.083 eigenvalues and a variance of 6.312%. These causes of cost overruns are client and consultant related and external and project-related. Adhering to contractual provisions would limit the client from initiating changes unprocedural, and this can be achieved by having detailed client briefs, as revealed by Olatunde and Alao (2017) and Akinradewo et al. (2019). Client-initiated changes should be undertaken within proper change management structures (Oyewobi et al., 2016; Shrestha et al., 2019) and the effect communicated fully before implementation. Decisions should also be promptly made according to the contractual timeframes as supported by Enshassi et al., (2009). Any deviation would be detrimental to the cost performance of the project through the initiation of claims by the contractor. If adequate project initiation is undertaken, prompt commencement of works should be undertaken after the award of the contract. This limits the effect of fluctuations on the cost performance of projects, amongst other aspects. Also, weather conditions play a significant role in affecting project cost performance, as suggested by Oyegoke et al. (2021). Any delays in the delivery of projects culminate in the generation of claims by contractors, affecting the cost of construction of infrastructural projects. Adequate risk management ensures that the effect of harsh weather conditions is adequately catered for in the construction costing.

*Component 4- Inadequate contractual management*

The fourth group of interrelated causes of cost overruns, as shown in Table 5, was named 'Inadequate contractual management' and accounted for 1.843 eigenvalues and a variance of 5.586%. These causes of cost overruns are client and consultant related and external and project-related. Delays of payment of work done come with remedies that increase the costs of construction of infrastructural projects (Amoatey and Ankrah, 2017). These include claims for interest, suspension of works and even determination of contracts. Consultants are encouraged to comprehensively advise clients on these aspects and ensure adequate funding arrangements for construction projects are made prior to the commencement of works. However, while this may work for private clients, public-sector clients are less likely to comply. Regardless, they should be advised of the consequences of delayed payment for work undertaken. Consultants can also allow for sufficient contingencies to reduce the effect of such actions, especially for public sector clients. Numerous disputes emanate from a failure to enforce such provisions as and when they occur (Sambasivan et al., 2017). Upholding professionalism by all the construction stakeholders is pertinent to circumventing any cost overruns that may arise from such actions (Dada, 2014). Also, collusion between consultants and contractors leads to a lack of enforcement of contractual provisions, as revealed by Park and Papadopoulou (2012), with clients bearing adverse cost effects. Adherence to and enforcement of contractual provisions is highly recommended for infrastructural construction projects.

*Component 5- Inadequate consultant supervision and corruption*

The fifth group of interrelated causes of cost overruns, as shown in Table 5, was named 'Inadequate consultant supervision and corruption' and accounted for 1.789 eigenvalues and a variance of 5.423%. These causes of cost overruns are client and consultant-related and external and project-related. The failure of contractors on sites is exacerbated by the lack of frequent and effective supervision by consultants, as supported by Ahiaga-Dagbui and Smith (2014). This may be due to needing more competent clerks of work or engineers' technical representatives on sites. Any delays or reworks that emanate from this failure by consultants will affect the cost performance of projects. Clients deserve the utmost attention and competent delivery of roles and responsibilities from consultants. Corruption has a negative impact on the cost of construction (Asiedu and Ameyaw, 2021). Instances where contractors are paid when the work has not been done satisfactorily or nominations are made due to prior unprofessional relationships add to the cost overrun concerns on infrastructural construction projects. Both these challenges require professional bodies to take a proactive role in raising awareness and taking decisive action where such contraventions occur.

*Component 6- Poor cost, financial and contractual professionalism*

The sixth group of interrelated causes of cost overruns, as shown in Table 5, was named 'Poor cost, financial and contractual professionalism' and accounted for 1.669 eigenvalues and a variance of 5.058%. These causes of cost overruns are client and consultant-related. Matching client requirements with their budget can be a challenge for consultants. Added to this, the scarcity of work can lead to some consultants acting unprofessionally and deliberately underestimating the initial project costs determined by Olatunde and Alao (2017). This action is detrimental to the project's cost performance and is avoidable. Upon execution, the actual costs of the project manifest, and this puts unwarranted pressure on clients to provide additional budgets. Unfortunately, the lack of knowledge of clients and their trust in consultants prevents them from taking remedial action beyond their contractual arrangements. Incentivised professional contracts can act to reduce this risk if any deviation from the initial project cost estimate will negatively affect the fees claimable by the consultants. This may go a long way in promoting professional conduct from the consultants. Related to this, Poor financial planning for the project and Errors and discrepancies in the contract documents, as also determined by Akinradewo et al., (2019) and Aje et al., (2017) respectively, are resolvable by incentivised professional contracts.

*Component 7- Poor cost planning, monitoring and control*

The seventh group of interrelated causes of cost overruns, as shown in Table 5, was named 'Poor cost planning, monitoring and control' and accounted for 1.480 eigenvalues and a variance of 4.485%. These causes of cost overruns are external and project-related, and contractor-related. Material and labour increases are expected in construction projects (Olatunji et al., 2018; Akinradewo et al., 2019; Afzal et al., 2020). However, in unstable economies, these expectations are difficult to forecast. If the type of contract is favourable towards fluctuations, the client bears the costs of excessive increases in material and labour prices. A solution would be to promote labour-only contracts when and if the client has enough capital to procure material. This can have a significant effect on reducing cost overruns.

Conversely, the nature of infrastructural projects having high construction costs may make it difficult for clients to invest substantial capital in procurement. Still, any proactive step taken by the client would reduce the effects of cost overruns. Unfortunately, contractors have had the challenge of poor cost monitoring and control for some time now (Chigara et al., 2013; Shehu et al., 2014). The root cause is their lack of competent manpower and/or technological advances to undertake such management requirements, as espoused by Oyegoke et al. (2021).

*Component 8- Project complexity and duration risks*

The eighth group of interrelated causes of cost overruns, as shown in Table 5, was named 'Project complexity and duration risks' and accounted for 1.361 eigenvalues and a variance of 4.125%. These causes of cost overruns are external and project-related. As stated by Lam and Siwingwa (2017) and Afzal et al. (2021), project complexity has significantly led to cost overruns on infrastructural projects. The lack of an experienced construction professional workforce means complex projects are not competently designed and managed and this has a knock-on effect of increasing construction costs. The cost of reworks is also substantial, with delays affecting cashflow projections of clients and increasing costs. The situation is worsened by the insistence on undertaking most of these projects using only local contractors (The Zimbabwe infrastructure development programme, 2021). Engaging international contractors through joint ventures would remedy the capability concerns and enhance the successful delivery of such projects. Linked to this cause is the issue of long project duration. In an unstable economy, long project durations exacerbate the risk of cost overruns. Hence, a short-term project-phased approach potentially reduces such risks.

*Component 9- Unstable economic fundamentals*

The ninth group of interrelated causes of cost overruns, as shown in Table 5, was named 'Unstable economic fundamentals' and accounted for 1.296 eigenvalues and a variance of 3.927%. These are external and project-related causes of cost overruns. The impact of unstable economic fundamentals is severe, especially in the study area where periodic economic downturns are significant. Abrupt changes in currencies and the consequent unpredictability of the exchange rate make cost budgeting of construction projects problematic, as also revealed by Mahmud et al. (2021). As clients migrate from one currency to another and try to navigate between official and non-official exchange rates, the construction costs tend to balloon, primarily due to the currency exchange rate unpredictability cost. Risk management, especially by Quantity surveyors, is strongly advocated. However, this still needs to exist within the competency framework for construction professionals. Generally, the unstable economic climate affects all the stakeholders (Habibi and Kermanshachi, 2018). Resolutions are implementable from policy pronouncements where the construction industry is preferentially treated in respect of a multi-currency approach to project implementation, access to foreign currency, and tax breaks for infrastructural projects.

*Component 10- Excessive use of prime cost sums and provisional sums*

The tenth group of interrelated causes of cost overruns, as shown in Table 5, was named 'Excessive use of prime cost and provisional sums' and accounted for 1.063 eigenvalues and a variance of 3.222%. This is an external and project-related cause of cost overruns. Prime cost and provisional sums have always been allowable and acceptable on construction contracts. However, this has seemingly been problematic, contributing to cost overruns, as supported by Asiedu and Ameyaw (2021). Their existence is due to the need for specialists to undertake some of the works, the need for certain suppliers to provide some of the material, allow for work that has to be done by statutory undertakings, and to allow for defined and undefined work in construction contracts (Ramus et al., 2008). Although they are essential, they are seemingly being exploited by construction professionals to either engage in collusion with nominated sub-contractors or main contractors during the execution of works and/or as an excuse for their failure to complete designs on time.

## 5. CONCLUSION

Infrastructural construction projects are inundated with cost performance concerns in developed and developing countries. This is despite their importance to the economies of developing countries like Zimbabwe. Although an excess of studies exists on the causes of such cost overruns, contextual distinctiveness makes it highly inappropriate to superimpose the existent findings on the Zimbabwean construction industry. Therefore, this research aimed to empirically determine the causes of cost overruns on infrastructural construction projects. The univariate analysis exposed the economic aspects of currency exchange rate unpredictability, poor financial planning, and an unstable economic climate as the most important causes. Enhanced economic and financial risk management is paramount to reducing the effect of such causes. Statistically significant differences due to designation (consultants' and contractor's quantity surveyors) were established for individual causes. The causes of cost overruns that consultant quantity surveyors perceived to be more severe as compared to contractors include Poor site management, Poor labour planning, Poor material planning, Poor organisation structure, Poor process procedures, Excessive use of prime cost and provisional sums, The poor calibre of contractors, Deficiencies with procurement methods, and Lack of coordination and communication between the consultants. These causes of cost overruns are contractor-related and consultant-related. This indicates a consensus from the consultants' quantity surveyors on the management deficiencies of contractors on infrastructural projects. The factor analysis generated ten component groups of interrelated causes of cost overruns as; Excessive use of prime cost sums and provisional sums, Unstable economic fundamentals, Project complexity and duration risks, Poor cost planning, monitoring and control, Poor cost, financial and contractual professionalism, Inadequate consultant supervision and corruption, Inadequate contractual management, Poor project change and initiation management and inclement weather, Poor organisational, communication and procurement structures, and project on-site and pre-contract planning inadequacies. These components reflect the entrenched challenges within construction stakeholders and contribute to the derivation of preventative strategies.

The study had the limitation of having quantity surveyors as the only respondents; however, this was an exploratory study, and their views were substantially vital as they have the required competency in cost and financial management of construction projects. Also, the causes of cost overruns for the survey were mainly selected from studies on developing countries. Although this potentially limited the respondents, this consideration was appropriate in considering the likely relevance of such causes to the study area. Further studies should incorporate the views of other construction stakeholders and assess statistically significant differences due to other demographic variables.

## 6. IMPLICATIONS FROM THE STUDY

The preventative strategies from the findings are numerous. Construction risk management should be instructed to both built environment students and professionals through tertiary education curricula and continuous professional development programmes to reduce the impact of unstable economic fundamentals. The implementation of contract-specific requirements through a short-term phased approach is supported. This will address the exposure to long-term risks. Also, the multi-currency approach will address currency shocks by using more stable currencies for construction projects. Third, the commencement of infrastructural construction projects with completely defined work and financial agreements with subcontractors is beneficial to the successful cost performance of projects. Competency in project management cycle phases of project initiation, planning and execution need to be inculcated in both contractor, consultant and client organisations to improve the management of projects. The lack of professional, ethical integrity of construction stakeholders substantially adds to the construction cost. With corruption activities becoming rampant, custodial sentences for such commercial crimes can go a long way in deterring such activities. In addition, construction organisations and professional bodies have the mandate and should intensify the training of their members against such behaviour.

## 7. REFERENCES

Adam A., Josephson P.E.B. and Lindahl G. (2017). Aggregation of factors causing cost overruns and time delays in large public construction projects. Engineering, Construction and Architectural Management. 24(3), 393-406.

Afzal, F., Yunfei, S., Junaid, D. and Hanif, M.S. (2020). Cost-risk contingency framework for managing cost overrun in metropolitan projects: using fuzzy-AHP and simulation, International Journal of Managing Projects in Business, 13(5), 1121-1139.

Afzal, F., Yunfei, S., Nazir, M., Bhatti, S.M. (2021). A review of artificial intelligence-based risk assessment methods for capturing complexity-risk interdependencies: Cost overrun in construction projects, International Journal of Managing Projects in Business, 14(2), 300-328.

Ahiaga-Dagbui D.D. and Smith S.D. (2014). Rethinking construction cost overruns: cognition, learning and estimation. Journal of Financial Management of Property and Construction. 19(1), 38-54.

Aje O.I., Olatunji O.A. and Olalusi O.A. (2017). Overrun causations under advance payment regimes. Built Environment Project and Asset Management. 7(1), 86-98.
Akinradewo, O., Aigbavboa, C., and Akinradewo, O. (2019). Revisiting causative factors of project cost overrun in building construction projects in Nigeria. In IOP Conference Series: Materials Science and Engineering. 640 (1), p. 012002 DOI:10.1088/1757-899X/640/1/0120002.
Amadi AI and Higham A. (2017). Latent geotechnical pathogens inducing cost overruns in highway projects. Journal of Financial Management of Property and Construction. 22(3), 269-285.
Amoatey, C.T and Ankrah, A.N O. (2017). Exploring critical road project delay factors in Ghana, Journal of Facilities Management, 15(2), 110-127
Amoatey, C.T., Ameyaw, Y. A., Adaku, E. and Famiyeh, S. (2015). Analysing delay causes and effects in Ghanaian state housing construction projects, International Journal of Managing Projects in Business, 8(1), 198-214
Asiedu R. O. and Adaku E. (2019). Cost overruns of public sector construction projects: a developing country perspective. International Journal of Managing Projects in Business. 13(1), 66-84.
Asiedu, RO and Ameyaw, C. (2021). A system dynamics approach to conceptualise causes of cost overrun of construction projects in developing countries, International Journal of Building Pathology and Adaptation, 39(5), 831-851.
Asiedu, R.O., Adaku, E. and Owusu-Manu, D. (2017). Beyond the causes: Rethinking mitigating measures to avert cost and time overruns in construction projects, Construction Innovation, 17(3), 363-380.
Ather S.M. and Balasundaram N. (2009). Factor analysis: Nature, mechanism and uses in social and management science research. Journal of Cost and Management Accountant, XXXVII (2), 15-25.
Benson J. and Nasser, F. (1998). On the use of factor analysis as a research tool. Journal of Vocational Education Research. 23(1), 13-33.
Blumberg, B, Cooper, D. R. and Schindler, P. S. (2008). Business research methods.2nd Ed. Berkshire: McGraw-Hill Higher Education.
Chigara, B. and Moyo, T. (2014). Factors affecting labour productivity on building projects in Zimbabwe. International Journal of Architecture, Engineering and Construction,3(1), 57-65.
Dada, J. O. and Jagboro, G.O. (2012). Core skills requirement and competencies expected of quantity surveyors: perspectives from quantity surveyors, allied professionals and clients in Nigeria. Australasian Journal of Construction Economics and Building. 12(4), 78-90.
Dada, M.O. (2014). The influence of project team relationships on cost growth, Journal of Financial Management of Property and Construction, 19(1), 76-94
Durdyev, S. (2021). Review of construction journals on causes of project cost overruns, Engineering, Construction and Architectural Management, 28(4), 1241-1260
El-Maaty, A.E.A., El-Kholy, A.M. and Akal, A.Y. (2017). Modeling schedule overrun and cost escalation percentages of highway projects using fuzzy approach, Engineering, Constructionand Architectural Management, 24(5), 809-827
Enshassi, A., Al-Najjar, J. and Kumaraswamy, M. (2009). Delays and cost overruns in the construction projects in the Gaza Strip, Journal of Financial Management of Property and Construction, 14(2), 126-151.
Famiyeh, S., Amoatey, C.T., Adaku, E. and Agbenohevi, C.S. (2017). Major causes of construction time and cost overruns, Journal of Engineering, Design and Technology, 15(2), 181-198.
Field, A. (2014). Discovering statistics using IBM SPSS statistics. 4th Ed. Los Angeles: Sage Publications.
Ghasemi, A. and Zahediasl, S. (2012). Normality tests for statistical analysis: A guide for non-statisticians. International Journal of Endocrinology Metabolism, 10(2), 486-489.
Guadagnoli, E. and Velicer, W. F. (1988). Relation of sample size to the stability of component patterns. Psychological Bulletin, 103(2), 265-275.

Habibi, M and Kermanshachi, S. (2018). Phase-based analysis of key cost and schedule performance causes and preventive strategies: Research trends and implications, Engineering, Construction and Architectural Management, 25(8), 1009-1033.

Kaiser, H. F. (1974). An index of factorial simplicity. Psychometrika, 39(1), 31-36.

Kothari, C. R. (2009). Research methodology; Methods and techniques.2nd Ed. New Delhi: New Age International Publishers.

Lam, T.Y.M and Siwingwa, N. (2017). Risk management and contingency sum of construction projects, Journal of Financial Management of Property and Construction, 22(3), 237-251.

Lu, W., Hua, Y. and Zhang, S. (2017). Logistic regression analysis for factors influencing cost performance of design-bid-build and design-build projects, Engineering, Construction and Architectural Management, 24(1), 118-132.

Magwaro-Ndiweni, L. (2016). Celebrating women in construction. Construction and Mining Magazine, 5(1), 10-11.

Mahmud A.T., Ogunlana, S.O. and Hong W.T. (2021). Key driving factors of cost overrun in highway infrastructure projects in Nigeria: a context-based perspective. Journal of Engineering, Design and Technology, 19(6), 1530-1555.

Marelli, A. F., Tondora, J. and Hoge, M. A. (2005). Strategies for developing competency models. Administration and Policy in Mental Health. 32(5/6), 533-561, doi: 10.1007/s10488-005-3264-0.

Mhlanga, P. (2017). Construction industry shrinks. The Financial Gazette, 23 February p. 3.

Mhlanga, P. (2018). Zim construction sector faces major hurdles. The Contractor, February, pp. 1-36. Available at: http://www.financialgazette.co.zw/wp-content/uploads/2018/10/Construction-Magazine-FEBRUARY.pdf. (Accessed on 02 February 2020).

Moser, C. and Kalton, G. (1979). Survey methods in social investigation.2nd Ed.Aldershot: Gower.

Moyo, T., Crafford, G. and Emuze, F. (2019). Decent working conditions for improved construction labour productivity on Zimbabwean building projects. Acta Structilia, 26(2), 1-38.

Olatunde, N.A. and Alao, O.O. (2017). Quantitative appraisal of cost and time performance of construction projects in public and private universities in Osun State, Nigeria, Journal of Engineering, Design and Technology, 15(5), 619-634.

Olatunji, O.A., and Orundami, A.O. and Ogundare, O. (2018). Causal relationship between material price fluctuation and project's outturn costs, Built Environment Project and Asset Management, 8(4), 358-371.

Oyegoke, A.S., Powell, R., Ajayi, S., Godawatte, GAGR and Akenroye, T. (2021). Factors affecting the selection of effective cost control techniques in the UK construction industry, Journal of Financial Management of Property and Construction, DOI 10.1108/JFMPC-07-2020-0050

Oyewobi, L. O., Jimoh, R., Ganiyu, B.O. and Shittu, A.A. (2016). Analysis of causes and impact of variation order on educational building projects, Journal of Facilities Management, 14(2), 139-164.

Park, Y.I. and Papadopoulou, T.C. (2012). Causes of cost overruns in transport infrastructure projectsin Asia", Built Environment Project and Asset Management, 2(2), 195-216, doi: 10.1108/20441241211280873

Perera, B.A. K. S., Hemajith, S. D. M., Ginige, K. and Amaratunga, R. D. G. (2007). Quantity surveyor as the technical appraiser in the Sri Lankan financial industry. Proceedings: Built Environment Education Conference, University of Salford, Manchester. Available at: http://usir.salford.ac.uk/9827/

Ramus, J, Birchall, S. and Griffiths, P. (2008). Contract Practice for Surveyors. 4th Ed. Oxford: Butterworth-Heinemann.

Sambasivan, M., Deepak, T.J., Salim, A. N. and Ponniah, V. (2017). analysis of delays in Tanzanian construction industry: Transaction cost economics (TCE) and structural equation modeling (SEM) approach, Engineering, Construction and Architectural Management, 24(2), 308-325.

Santos, R.O., Gorgulho, B.M., Alessandro de Castro, M., Fisberg, R. M., Marchioni, D.M. and Baltar, VT (2019). Principal component analysis and factor analysis: differences and similarities in Nutritional epidemiology application. Rev Bras Epidemiol, DOI: 10.1590/1980-549720190041
Saunders, M., Lewis, P. and Thornhill, A. (2016). Research methods for business students.7th Ed. London: Pearson Education.
Shayan, S., Kim, K. P., Ma, T., Freda, R. and Liu, Z. (2019). Emerging challenges and roles for quantity surveyors in the construction industry. Management Review: An International Journal. 14(1), 82-96
Shehu, Z., Endut, I.R., Akintoye, A. and Holt, G.D. (2014). Cost overrun in the Malaysian construction industry projects: a deeper insight. International Journal of Project Management, 32(8), 1471-1480, doi: 10.1016/j.ijproman.2014.04.004
Shrestha, P.P., Shrestha, K.K., and Zeleke, H.B. (2019). Probability of change orders and the effect on cost and schedule for new public-school buildings, Engineering, Construction and Architectural Management, 26(6), 1087-1104.
Steininger B.I. Groth M. and Weber B.L. (2021). Cost overruns and delays in infrastructure projects: the case of Stuttgart. Journal of Property Investment & Finance., 39(3), 256-282, DOI 10.1108/JPIF-11-2019-0144
Taherdoost, H. (2016). Validity and reliability of the research instrument: How to test the validation of a questionnaire/survey in research. International Journal of Academic Research in Management,5(3), 28-36.
The Global Competitiveness Report 2013–2014 (2013). The Global Competitiveness and Benchmarking Network,World Economic Forum, Geneva Available at: https://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2013-14.pdf, accessed 15 November 2021.
The Zimbabwe Infrastructure Development Programme (2021). Available at: http://veritaszim.net/node/4612, accessed on 15 November 2021
Watkins, M.W. (2018). Exploraory factor analysis: A guide to best practice, Journal of Black Psychology, 44(2), 219-246, DOI: 10.1177/0095798418771807
Yap, J.B.H., Lim, B.L., Skitmore, M. and Gray, J. (2021). Criticality of project knowledge and experience in the delivery of construction projects, Journal of Engineering, Design and Technology, DOI 10.1108/JEDT-10-2020-0413
Yong, A.G and Pearce, S. (2013). A beginner's guide to factor analysis: Focusing on Exploratory factor analysis. Tutorials in Quantitative Methods for Psychology, 9(2), 79-94, DOI10.20982/tqmp.09.2. p079
Zimbabwe National Statistics Agency (2020). Available at https://www.zimstat.co.zw/statistical-databases/, accessed on 15 November 2021

Journal of Construction Project Management and Innovation, 12(1): 87-108, 2022
ISSN 2223-7852


# Modus of tower cranes' efficient use on construction sites

**Oluseye Olugboyega[1*], Godwin Ehis Oseghale[2], Clinton Aigbavboa[3]**

[1&2]Faculty of Environmental Design and Management, Department of Building, Obafemi Awolowo University, Ile-Ife, Nigeria
[3]cidb Centre of Excellence, University of Johannesburg, South Africa

Email: oolugboyega@oauife.edu.ng*

## ABSTRACT
The choice, mixes, and setups of tower cranes do not just mean knowing the size, load limit, and functional boundaries of the system. There are fundamental factors that must likewise be thought of. To fill this gap, this study examines the considerations, configurations, and combinations that guarantee the efficient use of tower cranes in Nigeria. The investigation utilises a positivist philosophical framework. The data was gathered principally from the site managers working on forty-five construction sites in Lagos State, Nigeria. The discoveries from the examination conducted on the elicited data from the respondents uncovered that tower cranes are predominantly utilised for short-term and high-rise building projects. Lifting activities straightforwardly affect the project schedule and indirectly impact the project duration. The study concludes that the effective utilisation of tower cranes begins with tower crane load and location contemplations. Considerations for locating tower cranes should adhere strictly to tower crane setups, load type, and load quantity. The principal standard to be considered is the site limitations. The study recommends that building height, operator cost, cost of support system, soil condition, breakdown cycle and repair time are parameters that must be thought of while choosing tower cranes for a project.

**Keywords:** tower crane, site management, efficient use of tower crane, selection of tower crane

## 1. INTRODUCTION
Tower cranes are cranes that are typically fixed to the ground by either a concrete slab or by securing the crane to another kind of structure. Tower cranes are characterised both by their height and lifting capacity. The base is fixed to the mast of the tower, which decides the most extreme usable height and permits the crane to pivot since it is secured to the rotation unit. Tower cranes are important for the lifting and moving of heavy loads and are totally central to each construction site that requires working at height or having to move construction materials that would otherwise be immovable. Tower cranes are utilised on construction sites to lift heavy materials like steel and concrete. Large items are also moved by utilising tower cranes. Since tower cranes are slim compared with high-rise buildings, their lifting capacity can be effectively underrated based on appearance. Likewise, mishaps, including tower cranes, can bring about serious injuries, fatalities, and expensive harm to buildings and materials. Moreover, it will likewise prompt huge time and financial costs. This means that the utilisation of tower cranes should be informed by their configurations (Al Hattab et al., 2017). Loads could tumble from tower cranes because of operator incompetency, slipping, mechanical disappointment, and overloading (Sadeghi et al., 2021). While at least two tower cranes could be combined to forestall overloading, the selection of a tower crane genuinely should conform to their functional limits. Any other way, they will be exposed to structural stresses and irreversible damage.

As significant as the selection, blends, and configurations of tower cranes are to their utilization; studies have been quiet with regards to them. The focal point of researchers has been on models or algorithms for locating tower cranes (Nadoushani et al., 2018; Li et al., 2018; Abdelmegid et al., 2015; Kaveh and Vazirinia, 2017; Dasovi´c et al., 2019), tower crane accident and risk factors (Shin, 2015; Lingard et al., 2021; Kim and Kim, 2020; Jiang et al., 2021), and decision support for tower crane selection (Nayal et al., 2020; Al Hattab et al., 2017; Daniel et al., 2021; Shapira and Ben-David, 2017). These investigations have basically centered on optimizing the location of tower cranes.

Parameters influencing tower crane choice and productive use as far as designs and blends have not been completely represented. The choice, mixes, and setups of tower cranes do not just mean knowing the size, load limit, and functional boundaries of the system. There are fundamental factors that must likewise be thought of (Wang et al., 2021). To fill this gap and guarantee proficient utilisation of tower cranes, this study examines the (i) types of loads that tower cranes are considered for in Nigeria, (ii) significant considerations for deciding the most appropriate tower cranes in Nigeria, (iii) tower cranes' configurations and combinations on construction sites in Nigeria, and (iv) significant considerations for deciding the optimal location of tower cranes in Nigeria.

## 2. LITERATURE REVIEW

Many investigations have been conducted on tower crane locations. A portion of these examinations takes care of location optimization of tower cranes and assignment of material supply points in a construction site considering operating and rental costs (Nadoushani et al., 2018) and optimization algorithms to recognise the optimal type and location of an attached tower crane with the appropriate location of a material supply point (Li et al., 2018). The concentrate by Abdelmegid et al. (2015) fostered an optimization model to tackle tower crane location issues in construction sites utilising a Genetic Algorithm. The target of the study was to minimise the total transportation time. Kaveh and Vazirinia (2017) attempted to optimise tower crane location and material quantity between supply and demand points, while Dasovi c et al. (2019) proposed a working BIM method to optimise work facilities and tower crane locations on construction sites with monotonous tasks.

Having examined the optimal location for tower cranes, Kaveh and Vazirinia (2020) built on their previous work to propose a redesigned sine cosine algorithm for tower crane selection and layout problems. As for mutual interference, Briskorn and Dienstknecht (2018) proposed a mixed-integer programming model for tower crane selection and positioning. The study by Jeong et al. (2021) talked about another idea, the "lifting limit axis" concept, which was applied to develop an automatic arrangement (optimal arrangement) algorithm of the tower crane. Explicit investigations by Huang et al. (2019), Wu and Soto (2020), and Carlos and Mohamed (2017) have been seriously uncovered. Huang et al. (2019) proposed a cost-based selection and location optimization model for the tower crane to uncover the connection between the prefabrication ratio and the optimal selection and location of the tower crane. Results from the study exhibited that when the necessary prefabrication proportion is not under 30%, choosing a prefabricated beam is the most efficient for the construction project. When the number arrives at 50%, the mix of prefabricated columns and beams is the most prudent. The most minimal expense of the tower crane will be acquired when the supply point is situated at the midpoint of the long side of the construction project.

Wu and Soto (2020) proposed spatiotemporal modelling of lifting task scheduling for tower cranes, which comprises a lifting task scheduling optimization model with a tabu search and a lifting task scheduling display method with 4-D simulation. According to the study's findings, the average total time of the optimised lifting task scheduling, material preparation, and transfer times at the supply and demand points can be reduced by 25.82%. In addition, it was uncovered that the component data and relationship of lifting tasks can be plainly given utilising the proposed display method with 4-D simulation. Carlos and Mohamed (2017) introduced a modified ant colony optimization approach (MACA) and its application to the tower crane allocation problem. A comparison was conducted between the performances of Ant Colony Optimisation (ACO) and MACA in solving the tower crane allocation problem. The outcomes showed that MACA outperforms ACO and offers critical computing capabilities that can be utilised for other optimization problems. Regardless of how in-depth these investigations appear to be, they all emphasise the importance of tower crane positioning in relation to overall safety and cost, rather than efficiency.

A few investigations have zeroed in on factors adding to tower crane mishaps. The focal points of these investigations can be ordered as accident factors or risk factors. For instance, Shin (2015) explored the elements that contribute to accidents during tower crane installation and dismantling in Korea. The study uncovered that the competence of the workers, roles of stakeholders such as principal contractors in the tasks, deterioration of tower crane components, and working conditions for conducting the tasks are antagonistically influencing the safety of the tower crane installation and dismantling. Lingard et al. (2021) investigated causal and contributing variables to crane safety incidents in the Australian construction industry. A total of 77 causal and contributing variables were distinguished in the examination, which was found to work at numerous levels inside the working framework connected with the utilisation of cranes in the construction industry. The investigation likewise uncovered that these variables communicate with one another in complex ways inside and between levels of the work system. Kim and Kim (2020) inferred the significance ranking of accident factors of cab-control tower cranes by AHP analysis. The effects of the AHP examination uncovered that the highest-level component of the cab-control tower crane's accident was erection work. The study presumed that the inferred variables ought to be made due, and the necessary measures taken to diminish the tower crane accidents as per the positioning of accident factors. The study by Jiang et al., (2021) zeroed in on the system hazard analysis of tower cranes in various stages of a construction site.

Regarding risk factors, Jiang (2020) concentrated on the safety risk analysis and control of the tower crane. Through the subjective investigation of the accident tree, the minimum cut (diameter) set is gotten, on this premise, the primary significance of all fundamental occasions is arranged, and the principal factors influencing the safety accident of the tower crane are determined. Discoveries from the study give a premise to forestalling tower crane accidents and controlling tower crane risks. Zhou et al., (2018) analyzed tower crane safety from a complex sociotechnical framework viewpoint by carrying out both subjective and quantitative examination techniques. Through the principal component analysis, nine principal aspects of the tower crane safety system were recognized. They are: (i) tower crane equipment quality and dependability, (ii) tower crane safety management and upkeep, (iii) the tower crane safety program, (iv) workers' safety practice, (v) working environment, (vi) on-site working conditions for tower crane operation, (vii) supervisors' safety practice, (viii) auxiliary safety equipment, and (ix) government safety supervision.

The concentrate by Salihu et al., (2020) assessed safety risk factors during the installation and dismantling of tower cranes in construction sites in Nigeria. Results showed that abrasion (wear and tear of components such as bolts, nuts, or pins) is the most plausible element with a mean value of 3.63. It was observed that the fracture of a wire rope during dismantling had the highest degree of impact with a mean value of 4.63. The examiner reasoned that fracture of a wire rope during dismantling and abrasion (wear and tear of components such as bolts, nuts, or pins) are exceptionally influencing factors on safety during installation and dismantling. The study reasoned that the reception of a preventive maintenance strategy or routine check on the tower crane parts and components could assist with limiting the likelihood of occurrence and effect of the safety risk factors on-site.

Studies on the utilisation of tower cranes have been concerned about decision support for tower crane selection, overlapping work zones, and tower crane activities. Outstanding investigations in these classifications incorporate Nayal et al., (2020), Marzouk and Abubakr (2015), Al Hattab et al., (2017), Al Hattab et al., (2014), Daniel et al., (2021), and Shapira and Ben-David (2017). Nayal et al. (2020) explored the choice of tower crane utilising multi-rule decision-making techniques. The study also proposed a system of selection of tower cranes at the site using a multi-criteria decision-making (MCDM) model for the same. Marzouk and Abubakr (2015) introduced a system for the selection of tower crane types and locations at construction sites. The framework considered a decision-making model to select the tower crane type; an optimization model for the selection of the ideal number and location of tower cranes; and a 4D simulation model to simulate tower crane tasks.

Al Hattab et al. (2017) explored the effect of overlapping cranes, used on high-rise buildings, on functional adaptability, which is the harmony between schedule duration, crane utilization, and safety. The study showed that the outcomes of the balancing will depend on a few intensified factors, for example, the experience of planners and crane operators; the sequencing of basic versus non-basic exercises; and the general exertion and care taken when arranging tasks of overlapping cranes. It was deduced in the study that increasing overlap size can be gainful or troublesome depending on how appropriately planners assign overlapping cranes to workload demand, remembering that there are sure compromises while accomplishing functional adaptability. Al Hattab et al. (2014) optimised the use of two tower cranes by simulating the scheduling of tasks in the overlapping work zones to accomplish shorter operation durations and higher crane utilisation rates. An optimization model dependent on parametric variation was produced for studying two cranes by using, as input, the construction schedule detailed down to daily operations through look-ahead planning. The study guaranteed that the model provides a decent workload schedule for both cranes and accomplishes the best utilisation rates while diminishing inactive times to eventually support the production of the cranes while reducing project duration and cost. Daniel et al. (2021) proposed a philosophy to gauge the productivity of a construction site through the investigation of tower crane data. In the exploration, the activity of the tower crane was estimated by separating effective lifting operations using the load signal essentially.

The study by Shapira and Ben-David (2017) described equipment planning for multi-crane building construction sites. Different examinations in this area are a light-weight design of tower crane boom structure dependent on multi-objective optimization (Jia and Wan, 2015), seismic responses and dynamic attributes of boom tower cranes (Yao et al., 2018, 2019), payload swing control of a tower crane utilising a neural network-based input shaper (Fasih et al., 2020), and evaluation of the safe use of tower cranes on construction sites (Bamfo-Agyei and Atepor, 2018). There is adequate data in the above examinations to recommend that choosing the appropriate type, number, and locations of cranes is reliant upon the site's layout and logistics, expected workload demand, and project surroundings such as traffic and adjoining buildings. It was additionally clarified that tower crane layout design and planning within construction sites is a typical construction technical issue. Cranes must be chosen and their on-site locations have to be determined so that each demand area is associated with its supply area.

Specifically, studies on location optimization have shown that deciding the location of the tower crane is a fundamental task of layout planning. As indicated by these examinations, the optimization of tower crane location relies upon many interrelated variables, including shape and size of the buildings; type and quantity of required materials; crane configurations; crane type; and construction site layout. These elements differ starting with one project to the next, coming about due to muddled site layout strategies and approaches. Notwithstanding, tower cranes are basic equipment that should be appropriately planned and matched with construction work on-site so that operations can be performed proficiently, securely, and accurately. Additionally, in the event that the crane's essential qualities don't match the work's necessities, then it might prompt huge impacts as far as significant cost, potential postponements, and dangerous work conditions. The utilisation and choice of tower cranes requires more than location optimization and making arrangements for safety on the grounds that their structures, foundations, and presence on the site are generally for as long as the heavy construction phases continue. In choosing a tower crane, the characteristics, configurations, and potential mixes of different tower cranes available should be considered against the prerequisites forced by the loads to be taken care of and the environmental factors wherein the tower crane will operate. Assuming this isn't done, effective utilisation of the tower crane is not ensured (Abdelmegid et al., 2015).

## 3. METHODOLOGY

In exploring the considerations, configurations, and combinations underlying the efficient use of tower cranes on construction sites; this study utilized a positivism philosophical framework. The examination depended on the research framework in Figure 1. The framework clarifies that:

- The efficiency of tower cranes generally relies upon their type, number, location, and load consideration. As the number of work assignments and the demand for tower cranes increases, planners might encounter troubles in settling on a fitting choice with regard to the location of tower cranes. A poor decision, notwithstanding, is probably going to have critical adverse consequences, which will prompt extra expenses and potential postponements. The load considered for the tower crane will advise the type of tower crane to be selected, its configurations, and the plausibility of joining at least two tower cranes.
- To decide the appropriate tower crane type and reasonable positions, many variables should be thought about. These impressive variables incorporate tower crane data, construction project data, construction site data, and construction materials data. Tower crane data incorporate the heaviest lift and the largest lifting radius.
- The mounting, structures and jib of a tower crane should be considered to decide the most reasonable tower crane configurations.
- A single tower crane could be utilized or joined as a double or multiple tower crane contingent upon the load necessity.

Figure 1 illustrates the proposed factors, configurations, and potential mixes that would guarantee the productive utilisation of tower cranes. Construction site managers overseeing ongoing sites with tower cranes were purposively selected as the study populace. This was hinged on the fact that the actual and detailed plan of tower cranes was prepared by the construction site managers. The site manager readies the subtleties included in the Construction Method Plan contingent upon the actual project scope, status, and type of cranes available. Furthermore, the site manager prepares the Tower Crane Assignment Schedule, which is an important document for planning the productive use of the tower crane(s). A pilot study to identify ongoing sites with tower cranes was conducted in Lagos State, Nigeria. The choice of Lagos State as the study area was informed by its status as the hub of construction activities in Nigeria. At the end of the pilot study, an aggregate of 45 ongoing sites with tower cranes was identified and used to decide the target population for the study. A full enumeration of the distinguished 45 construction sites was embraced.

Data was gathered principally from the site managers working on the identified construction sites. The questionnaire utilised for the survey evoked information on respondents' company profiles, contemplations for deciding the most proper tower cranes, contemplations for deciding the ideal location of tower cranes, techniques guiding the location of tower cranes, sorts of load that tower cranes are considered for, and tower cranes' configurations and combinations on construction sites. Table 1 shows the profile of the construction organisations that the surveyed site managers were working for. The majority of site managers (40%) work for companies whose primary business is building and civil construction. Most (33.3%) of the site managers indicated that their companies have 50 employees and 101-150 employees. A few (20%) of the companies have existed for over 21 years, while most (40%) of the companies operate at the national level.

The data collected were analysed using the mean score, z-score, Analysis of Variance, and Tukey HSD Post Hoc test. For the mean score analysis, the significance level of the scores was determined as follows: very low (1.00 – 1.80), low (1.81 – 2.60), medium (2.61 – 3.20), high (3.21 – 4.20), and very high (4.21 – 5.00). The z-score analysis supplements and permits the correlation of mean scores by normalising the dispersion. It was calculated according to the formula given by Abdi (2007). In deciding the significance level of the z-scores, a variable was viewed as significant if its z-score was positive and insignificant if the z-score was negative.

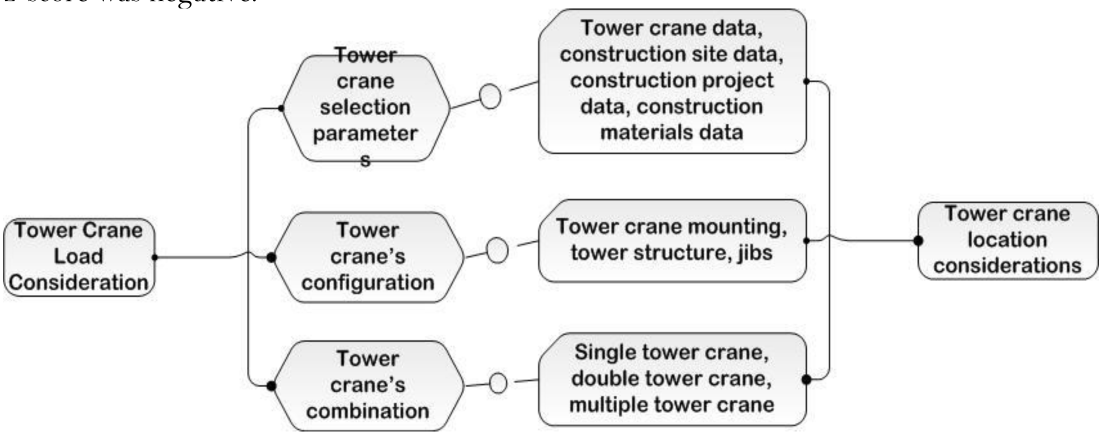


**Figure 1:** research framework

**Table 1:** Respondents' company profile

| Section | Options | Frequency | Percent |
|---|---|---|---|
| Area of operation | Building construction | 12 | 26.7 |
| | Industrial construction | 6 | 13.3 |
| | Civil construction | 6 | 13.3 |
| | Building & civil construction | 18 | 40.0 |
| | Special construction | 3 | 6.7 |
| | Total | 45 | 100.0 |
| Company size | < 50 employees | 15 | 33.3 |
| | 51-100 employees | 12 | 26.7 |
| | 101-150 employees | 15 | 33.3 |
| | >151 employees | 3 | 6.7 |
| | Total | 45 | 100.0 |
| Years of experience of respondents | 6-10 | 6 | 13.3 |
| | 11-15 | 5 | 11.1 |
| | 16-20 | 10 | 22.2 |
| | 21 years & above | 24 | 53.3 |
| | Total | 45 | 100.0 |
| Company age | 6-10 | 12 | 26.7 |
| | 11-15 | 12 | 26.7 |
| | 16-20 | 12 | 26.7 |
| | 21 years & above | 9 | 20.0 |
| | Total | 45 | 100.0 |

| | | | |
|---|---|---|---|
| Region of operation | Local-level | 6 | 13.3 |
| | State-level | 6 | 13.3 |
| | Interstate | 9 | 20.0 |
| | National level | 18 | 40.0 |
| | International level | 6 | 13.3 |
| | Total | 45 | 100.0 |

# 4. RESULTS

## 4.1 Tower cranes load considerations

The tower crane load configuration on construction sites was researched by eliciting information on the use of tower cranes for various kinds of loads and projects. Utilizing a 5-point Likert scale, the site managers were approached to demonstrate their level of understanding (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) with the kinds of loads and projects that tower cranes were considered for on construction sites. The data collected were analysed using the mean score and z-score (see Table 2). The outcomes from the mean score analysis uncovered that 16 unique kinds of loads were exceptionally considered for lifting by tower cranes on construction sites. Only precast materials were very highly considered for lifting by tower cranes. On the basis of this finding, Huang et al. (2019) have connected prefabrication with the utilisation of a tower crane. This recommends that the tower crane is a significant consideration for load lifting in assembly and erection processes involving precast and prefab materials.

The mean score investigation further showed that tower cranes were not generally utilised for lifting workers to work stations, machinery and equipment, roof covering and accessories, roof trusses, and plumbing fixtures. Plumbing apparatuses and roof coverings may not really be weighty and, in this way, may not need lifting by a tower crane. Notwithstanding, roof trusses, because of their size and weight, should be lifted by the tower crane. This outcome appears to be astonishing. The main clarification for the non-lifting of roof trusses with tower cranes on construction sites could be that the surveyed sites were, for the most part, high-rise buildings and, in this manner, didn't need the utilisation of roof trusses. In an alternate manner, it may be the case that the trusses were lifted into position utilising different strategies like the pulley system because of the tight timetable of the tower crane.

The non-lifting of work and machinery with tower cranes could be because of the requirement for safety. The safe use of the tower crane doesn't uphold the lifting of live loads like workers (Lingard et al., 2021; Kim and Kim, 2020). The aftereffect of the Z-score analysis gave an elective translation of the degree of significance of the loads considered for the tower crane. As displayed in Table 2, the outcomes revealed that tower cranes are principally utilised for lifting purlins, plumbing fixtures, workers to work stations, precast materials, formwork, curtain wall, precast façade elements, reinforcement, concrete, and blocks. The results of the Z-score analysis for the most part upheld the discoveries from the mean score analysis. In any case, plumbing fixtures and workers were uncovered by Z-score analysis as critical loads lifted by tower cranes on construction sites. These loads recorded medium-level significance in mean score analysis. Considering the two outcomes, it may very well be surmised that plumbing fixtures and workers were lifted using tower cranes on some construction sites. The sort of plumbing fixtures lifted using the tower crane might contrast with the construction sites. Nonetheless, the lifting of workers with a tower crane is a safety risk factor, as verified by Jiang (2020) and Zhou et al. (2018).

Likewise, Table 2 showed the mean and Z-score analysis of the use of tower cranes for various kinds of projects. The results of the mean score analysis uncovered that tower cranes were profoundly considered for short-term projects, medium-sized and large projects, and high-rise building projects. This helps the non-thought-of tower cranes for lifting roof trusses, as indicated by the respondents. Roof trusses are not common with high-rise buildings and could, without much of a stretch, be lifted into position utilising other non-tower crane strategies for medium-sized projects. The consequences of the Z-score analysis uncovered that tower cranes are, for the most part, utilised for short-term projects and high-rise building projects. The two outcomes complemented one another and immovably settled the utilisation of tower cranes for short-time and high-rise building projects.

**Table 2:** Load considered for lifting by tower cranes

| **Usage of Tower Crane for different types of projects** | | | | | |
|---|---|---|---|---|---|
| Usage of tower crane for different types of loads | Mean score | The significance level for the mean score | Standard deviation | z-score | The significance level for z-score |
| Project in restricted locations | 2.4667 | Low | .89443 | -0.29 | Insignificant |
| Wall ties | 2.9333 | Medium | 83.39348 | -0.00 | Insignificant |
| Electrical fixtures | 3.0667 | High | 1.19469 | -0.46 | Insignificant |
| Roof trusses | 3.0667 | Medium | 1.19469 | -0.46 | Insignificant |
| Plumbing fixtures | 3.0667 | Medium | 1.35512 | 0.38 | Significant |
| Roof covering and accessories | 3.1333 | Medium | 1.15994 | -0.42 | Insignificant |
| Balustrade | 3.1333 | Medium | 1.32459 | -0.36 | Insignificant |
| Machinery and equipment | 3.1333 | Medium | 1.15994 | -0.42 | Insignificant |
| Workers to work station | 3.2000 | Medium | 1.12006 | 0.31 | Significant |
| HVAC fixtures | 3.2667 | Medium | 1.13618 | -0.31 | Insignificant |
| Floor wall | 3.2667 | High | 1.19469 | -0.29 | Insignificant |
| Steel materials | 3.3333 | High | 1.20605 | -0.23 | Insignificant |
| Furniture and fixture | 3.4000 | High | 1.37179 | -0.15 | Insignificant |
| Scaffolding | 3.4000 | High | 1.37179 | -0.15 | Insignificant |
| Motor | 3.4000 | High | 1.37179 | -0.15 | Insignificant |
| Doors and window frames | 3.4000 | High | 1.15601 | -0.81 | Insignificant |
| Installation of prefab arrangements | 3.4000 | High | 1.15601 | -0.81 | Insignificant |
| Painting and interior decoration materials | 3.4667 | High | 1.27208 | -0.16 | Insignificant |
| Medium & large project | 3.4667 | High | 1.15994 | -0.13 | Insignificant |
| Formwork | 3.6667 | High | 1.14812 | 0.04 | Significant |
| Curtain wall | 3.6667 | High | .95346 | 0.05 | Significant |
| Precast facade elements | 3.6667 | High | 1.02247 | 0.05 | Significant |
| Reinforcement | 3.7333 | High | 1.13618 | 0.08 | Significant |
| Short time project | 3.7333 | High | 1.13618 | 0.11 | Significant |
| Concrete | 3.8000 | High | 1.17937 | 0.18 | Significant |
| High-rise building project | 3.9333 | High | .78044 | 0.41 | Significant |
| Purlins | 4.0000 | High | 2.15322 | 0.18 | Significant |
| Precast materials | 4.4000 | Very high | 13.1640 | 0.06 | Significant |
| Block/bricks | 4.8667 | High | 4.77017 | 0.26 | Significant |

## 4.2 Tower crane selection parameters

Data on the criteria considered in choosing tower cranes on construction sites was evoked from the surveyed site managers. The criteria were arranged into four groups: construction materials data, construction project data, construction site data, and tower crane data. Mean score analysis was used to examine the level of significance of the criteria, while Z-score analysis was used to confirm the mean score examination and set up extremely large rules. As introduced in Table 3, the mean score analysis uncovered that the height of a building is profoundly considered as construction project data and soil condition is exceptionally considered as construction site data. For tower crane data, transportation cost, disassembly cost, maintenance and depreciation, operators' cost, the capacity of crane required, and cost of support system are exceptionally thought to be in choosing tower cranes on construction sites. The breakdown cycle and repair time are very highly considered.

The outcomes from the Z-score analysis upheld the mean score analysis. As displayed in Table 3, the height of the building (construction project data), operator cost, cost of support system, and breakdown cycle and repair time (tower crane data) are the primary criteria considered in choosing tower cranes on construction sites. Soil conditions are fundamental for the stability of the tower crane (Yao et al., 2018). This explains why it was the main construction site data profoundly considered in the tower crane choice. Shin (2015) featured the significance of tower crane installation and dismantling. This current study likewise observed tower crane installation and dis-assembly as a feature of the exceptionally considered tower crane data.

**Table 3:** Criteria affecting the selection of Tower Crane on construction sites

| Criteria | Mean score | The significance level for the mean score | Standard deviation | Z-score | The significance level for z-score |
|---|---|---|---|---|---|
| **Construction materials data** | | | | | |
| Weight & size of materials | 2.6000 | Low | 1.09545 | -0.92 | Insignificant |
| Types of material required on site | 3.0667 | Medium | 1.00905 | -0.55 | Insignificant |
| **Construction project data** | | | | | |
| Project duration & size | 2.3333 | Low | 1.14812 | -1.14 | Insignificant |
| Availability of expertise | 2.3333 | Low | 1.08711 | -1.19 | Insignificant |
| Productivity target | 2.6667 | Medium | 1.20605 | -0.79 | Insignificant |
| Construction methodology and programme | 2.6667 | Medium | 1.08711 | -0.87 | Insignificant |
| Height of building | 4.0000 | High | 7.32989 | 0.05 | Significant |
| **Construction site data** | | | | | |
| Site layout plan | 2.3333 | Low | 1.14812 | -1.12 | Insignificant |
| Site constraint | 2.6667 | Medium | 1.20605 | -0.79 | Insignificant |
| Noise and dust | 2.8667 | Medium | 1.21730 | -0.62 | Insignificant |
| Site neighborhood | 3.1333 | Medium | 1.09959 | -0.44 | Insignificant |
| Soil condition | 3.4667 | High | 1.15994 | -0.13 | Insignificant |
| **Tower crane data** | | | | | |
| Weather condition | 2.5333 | Low | 1.21730 | -0.89 | Insignificant |
| Space requirement | 2.6667 | Medium | 1.08711 | -0.87 | Insignificant |
| Availability of spare parts | 2.8667 | Medium | .96766 | -0.78 | Insignificant |
| Availability of parts | 3.0000 | Medium | 1.10782 | -0.55 | Insignificant |
| Installation cost | 3.2000 | Medium | 1.34164 | -0.31 | Insignificant |
| Rental cost | 3.2000 | Medium | 1.28982 | -0.30 | Insignificant |
| Transportation cost | 3.2667 | High | 1.35512 | -0.26 | Insignificant |
| The capacity of the crane required | 3.2667 | High | 1.19469 | -0.29 | Insignificant |
| Disassemble cost | 3.3333 | High | 2.35488 | -0.12 | Insignificant |
| Maintenance and depreciation | 3.4667 | High | 1.15994 | -0.13 | Insignificant |
| Operators cost | 3.6000 | High | 1.21356 | 0.00 | Significant |
| Cost of support system | 3.9333 | High | 12.50891 | 0.03 | Significant |
| Breakdown cycle & repair time | 4.0000 | Very high | .90453 | 0.43 | Significant |

### 4.3 Tower cranes' configurations and combinations on construction sites

Table 4 shows the results of the mean score and Z-score investigations of the tower crane designs and mixes as indicated by the respondents. The consequences of the mean score analysis uncovered that the telescope tower is the most exceptionally utilised tower structure on construction sites. The exceptionally utilised jibs incorporate fixed radius jibs, horizontal trolley jibs, and articulated jibs. The mean score analysis did not give a reasonable outcome on the type of tower crane mounting. This suggests an absence of emphasis on tower crane setups among the site managers.

The Z-score analysis revealed that horizontal trolley jibs were the most extensively used jib. Combining the outcomes from the Z-score and mean score examinations, it may very well be deduced that site managers just connected significance to jibs as the fundamental tower crane components. Concerning mixes of tower cranes on construction sites, the mean score analysis and Z-score analysis uncovered that double tower cranes are dominatingly utilised on construction sites. This proposes that site managers are productively using tower cranes on construction sites by combining them in twos.

**Table 4:** Tower crane configurations and combination

| Tower Crane mounting on construction sites | Mean score | The significance level for the mean score | Standard deviation | Z-score | The significance level for z-score |
|---|---|---|---|---|---|
| Static base | 2.8000 | Medium | 1.05744 | -0.77 | Insignificant |
| Rail | 3.0000 | Medium | .90453 | -0.67 | Insignificant |
| Crawler | 3.0667 | Medium | 1.00905 | -0.55 | Insignificant |
| Truck | 3.1333 | Medium | .72614 | -0.69 | Insignificant |
| **Tower structures on construction sites** | | | | | |
| Mono tower | 2.9333 | Medium | .68755 | -1.00 | Insignificant |
| Inner & outer tower | 2.9333 | Medium | 1.00905 | -0.68 | Insignificant |
| Telescope tower | 3.4667 | High | .89443 | -0.17 | Insignificant |
| **Jibs on construction sites** | | | | | |
| Rear pivoted luffing jib | 2.9333 | Medium | 1.25045 | -0.54 | Insignificant |
| Fixed radius jib | 3.4000 | High | 1.15601 | -0.18 | Insignificant |
| Articulated jibs | 3.5333 | High | 1.03573 | -0.08 | Insignificant |
| Horizontal trolley jibs | 4.2000 | High | 5.23797 | 0.11 | Significant |
| **Combinations of a tower crane on construction sites** | | | | | |
| Multiple tower crane | 2.5333 | Low | .62523 | -1.74 | Insignificant |
| Single tower crane | 3.0667 | Medium | 1.07450 | -0.51 | Insignificant |
| Double tower crane | 3.4000 | High | .71985 | 0.00 | Significant |

### 4.4 Considerations for determining the optimal location of tower cranes

Two questions were used to investigate the factors that should be considered when determining the best location for tower cranes. First and foremost, site managers were asked to respond to questions on criteria considered in locating tower cranes on construction sites using a 5-point Likert scale. The mean score and Z-score analysis of the reactions are presented in Table 5. Second, the site managers were approached to show their level of concurrence with the techniques guiding the location of the tower crane on construction sites. Table 6 gives the mean score and Z-score analysis conducted on the responses. The mean score examination revealed that site constraint, type and quantity of required material, crane configuration and type, as well as hook movement and height, are the primary measures influencing tower crane location, as shown in Table 5. The Z-score analysis just upheld site constraints as the fundamental basis influencing tower crane location. This implies that any remaining variables are influenced by site constraints. For instance, safety, jib length, crane capacity, tower crane configuration and type, as well as the size and shape of buildings, are associated with the site constraints. Site limitations will unquestionably influence the attributes of buildings and tower cranes.

Table 6 shows that every one of the recognised procedures should be followed as a direction for locating the tower crane. Only the determination of the weight of loads to be lifted and optimising lifting motion for the tower crane were not shown as fundamental techniques by the respondents. Both mean score and Z-score examinations settled on the significance of the identified procedures. It is obvious from the outcomes that load consideration, tower crane configurations, and planning of tower crane activities are fundamental in locating tower cranes. Tables 7 and 8 show the results of the descriptive statistics, the Analysis of Variance (ANOVA), and the Tukey post hoc tests that were conducted to determine if there are statistical differences between the mean item scores for the ratings indicated by the respondents. The ANOVA results revealed that the F-ratio value is 1.54544 and the p-value is.219703. The result is not significant at p.05, indicating that no statistically significant difference between groups was found using ANOVA. The Tukey post hoc test also revealed that there was no significant difference between the various pairs of means.

**Table 5:** Criteria affecting the location of Tower Crane on construction sites

| Criteria | Mean score | The significance level for the mean score | Standard deviation | Z-score |
|---|---|---|---|---|
| Safety | 2.3333 | Low | .87905 | -1.47 |
| Shape and size of the building | 3.0667 | Medium | 1.25045 | -0.44 |
| Jib length | 3.0667 | Medium | 1.25045 | -0.44 |
| Crane capacity | 3.1333 | Medium | 1.15994 | -0.42 |
| Hosting movement | 3.2000 | Medium | .99087 | -0.41 |
| Hook movement &height | 3.2667 | High | 1.30384 | -0.27 |
| Crane configuration & type | 3.4000 | High | 1.37179 | -0.15 |
| Type & quantity of required material | 3.4667 | High | 1.15994 | -0.13 |
| Site constraint | 3.5333 | High | 1.42382 | 0.01 |

**Table 6:** Procedures guiding the location of Tower Crane on construction sites

| Procedures | Mean score | The significance level for the mean score | Standard deviation | Z-score | The significance level for z-score |
|---|---|---|---|---|---|
| Determination of the weight of loads to be lifted | 2.8667 | Medium | 1.09959 | -8.33 | Insignificant |
| Optimizing lifting motion for the tower crane | 3.0667 | Medium | 1.25045 | -0.44 | Insignificant |
| Identifying feasible tower crane location | 3.1333 | Medium | 1.03573 | -0.47 | Insignificant |
| Identifying obstacles and work zones on construction site | 3.4000 | High | 1.09545 | -0.19 | Insignificant |
| Selecting appropriate jibs | 3.5333 | High | 1.21730 | -0.07 | Insignificant |
| Determination of the coverage area for the tower crane | 3.6000 | High | 1.21356 | -0.01 | Insignificant |
| Calculating safe working loads for the tower crane | 3.6000 | High | .96295 | -0.01 | Insignificant |
| Listing out load to be lifted | 3.6667 | High | 1.26131 | 0.04 | Significant |
| Creating a safety zone around the tower crane coverage area | 3.6667 | High | 1.14812 | 0.04 | Significant |
| Preparing tower crane task schedule | 3.7333 | High | 1.25045 | 0.09 | Significant |
| Selecting appropriate sling angle and factor | 3.7333 | High | 1.13618 | 0.08 | Significant |
| Selection of appropriate rigging method | 3.8667 | High | 1.15994 | 0.22 | Significant |
| Selection of appropriate demand and supply points for the loads | 4.0000 | High | 1.16775 | 0.34 | Significant |
| Analyzing the working spaces required for the tower crane | 4.0667 | High | .86340 | 0.52 | Significant |

**Table 7:** One-way ANOVA for non-homogeneity of variance

| **Result Details** | | | | |
|---|---|---|---|---|
| ***Source*** | ***SS*** | ***df*** | ***MS*** | |
| Between-treatments | 0.5828 | 4 | 0.1457 | $F = 1.54544$ |
| Within-treatments | 2.357 | 25 | 0.0943 | |
| Total | 2.9398 | 29 | | |

**Table 8:** Post Hoc Tukey HSD

| *Pairwise Comparisons* | | $HSD_{.05} = 0.5206$ $HSD_{.01} = 0.6448$ | $Q_{.05} = 4.1534$ $Q_{.01} = 5.1439$ |
|---|---|---|---|
| **$T_1$:$T_2$** | $M_1 = 3.24$<br>$M_2 = 3.22$ | 0.02 | $Q = 0.18$ ($p = .99994$) |
| **$T_1$:$T_3$** | $M_1 = 3.24$<br>$M_3 = 3.32$ | 0.08 | $Q = 0.62$ ($p = .99185$) |
| **$T_1$:$T_4$** | $M_1 = 3.24$<br>$M_4 = 3.59$ | 0.34 | $Q = 2.75$ ($p = .32206$) |
| **$T_1$:$T_5$** | $M_1 = 3.24$<br>$M_5 = 3.47$ | 0.22 | $Q = 1.77$ ($p = .72092$) |
| **$T_2$:$T_3$** | $M_2 = 3.22$<br>$M_3 = 3.32$ | 0.10 | $Q = 0.80$ ($p = .97907$) |
| **$T_2$:$T_4$** | $M_2 = 3.22$<br>$M_4 = 3.59$ | 0.37 | $Q = 2.93$ ($p = .26457$) |
| **$T_2$:$T_5$** | $M_2 = 3.22$<br>$M_5 = 3.47$ | 0.24 | $Q = 1.95$ ($p = .64597$) |
| **$T_3$:$T_4$** | $M_3 = 3.32$<br>$M_4 = 3.59$ | 0.27 | $Q = 2.13$ ($p = .56922$) |
| **$T_3$:$T_5$** | $M_3 = 3.32$<br>$M_5 = 3.47$ | 0.14 | $Q = 1.15$ ($p = .92349$) |
| **$T_4$:$T_5$** | $M_4 = 3.59$<br>$M_5 = 3.47$ | 0.12 | $Q = 0.97$ ($p = .95696$) |

## 5. DISCUSSION OF FINDINGS

Proper planning of tower crane utilisation is basic to their effective use. Numerous scientists have conceived that optimising the location of tower cranes will ensure their effective use. According to the current study, the productive utilisation of tower cranes is dependent on determining the most appropriate tower crane, determining the ideal location of the tower crane, using the tower crane for the appropriate load, and determining the ideal tower crane configurations and combinations. These contentions were operationalized by surveying site managers overseeing ongoing construction sites with tower cranes in Lagos State, Nigeria. The discoveries from the examination conducted on the elicited data from the respondents uncovered that tower cranes are principally considered for lifting heavy and cumbersome materials; the lifting of light materials with tower cranes is not conservative and effective; and the lifting of live loads with tower cranes is not safe.

The investigation likewise discovered that tower cranes are predominantly utilised for short-term projects and high-rise building projects. Lifting activities straightforwardly affect the project schedule and have an indirect impact on project duration. Consequently, the use of tower cranes in high-rise buildings where there are lots of lifting operations could be because of the need to decrease the project time and cost. The safety and thoroughness of pouring concrete in ongoing upper floor levels may suggest that tower cranes be used for high-rise buildings. It was amazing to observe that the tower crane was not being utilised for projects in confined areas. This could be because of the absence of specialised ability with respect to the site managers or safety requirements in the location. It may be the case that tower cranes are predominantly utilised for short-term projects in view of the cost-saving measures and the risk of leaving tower cranes for a longer period on sites.

It was found in this research that construction materials and construction site data were not viewed as significant while choosing tower cranes on construction sites. Among the construction project data, only the height of the building was typically considered as a significant element in the choice of tower cranes. This could be on the grounds that tower cranes are chiefly utilised for high-rise building projects. The operator's cost, cost of support system, and breakdown cycle and repair time were the criteria that were indicated as influencing the choice of tower cranes. This suggests that tower crane planning only accentuates the cost of operating tower cranes. Other important factors such as available space, climate, and crane capacity were not considered. This could be connected to the contractor's quest to boost profit to the detriment of safety and productivity. Daniel et al. (2021) had previously affirmed that productivity is the main criteria in analysing tower crane data. The discoveries of this current study are demonstrated in any case.

Studies, for example, Jiang et al., (2021), Lingard et al., (2021), and Jiang (2020), have accentuated the need to focus on tower crane configurations for safety and efficiency. This current study inspected tower crane configuration designs in practice. Moreover, Shapira and Ben-David (2017) and Bamfo-Agyei and Atepor (2018) have exhibited the potential outcomes of combining tower cranes on sites. This current study went above and beyond to explore the occurrence of tower crane mixes on sites. The discoveries recommend that telescope towers and horizontal trolley jibs are the normal parts of tower crane configurations on construction sites. This could be on the grounds that the telescope tower is the most adaptable tower structure and represents the norm by which other tower structures are measured. The telescope tower gives utility, adaptability, and the means to lift weighty loads. The telescope tower has the highest reach and allows for height adjustment as needed. It could likewise be clarified that the site managers opt for horizontal trolley jibs since they give adaptability and support the lifting of weighty loads. The discoveries implied that the mission to accomplish higher tower crane utilisation rates has prompted the common use of double tower cranes on construction sites. The utilisation of two-story tower cranes is related to fewer on-site problems and deferrals.

It arose out of the discovery that site constraints are the main criterion influencing tower crane location. The emphasis on cost and safety as criteria in tower crane location is predominant in the literature (Huang et al., 2019; Al Hattab et al., 2017). The discoveries of this study uncovered that there are more significant contemplations in tower crane locations. The main criterion was viewed as site constraints. This finding conflicts with the convention and focal point of location optimization studies. Those examinations have stressed safety. The results of this current study propose that the focus of location optimization ought to be site constraint. This is on the grounds that tower crane safety will be dictated by the accessible space on site. At the point when the site constraints have been calculated into the tower crane location, the safety issue would have been provided for. Scarcely any researchers have glanced at site constraints as the significant standard to be considered in tower crane location.

Discoveries on the techniques guiding the location of tower cranes on construction sites revealed that the main advance is dissecting the working spaces required for the tower crane. These further stresses the significance of site constraints as the main basis for tower crane location. Site constraints are usually considered in the tower crane working space analysis.

### 5.1 Practical implications

The discoveries of this study have wide-reaching implications for site management training and skill development, tower crane assignment schedules, and planning of double tower cranes. To start with, there is a requirement for a code of practise on directing the utilisation and planning of tower cranes on Nigerian construction sites. The code will support consistency and ethics in the utilisation of tower cranes. It will help site managers deal with planning dilemmas related to tower crane location and selection. It will likewise serve as a significant reference for upgrading safety and optimising the tower crane assignment schedule. The code ought to broadly dissect the tower crane selection and location criteria and procedures. The usage of tower cranes in accordance with its setups should likewise be stressed in the code.

Second, training on the effective utilisation of tower cranes ought to be part of the site management training for the experts. It is appropriate for site managers to comprehend that a tower crane is a more reasonable method for addressing the lifting needs of any construction project. Meeting the lifting needs should be done effectively and economically. For instance, focusing on the utilisation of tower cranes for tall building construction and focusing on the utilisation of tower cranes for lifting heavy loads. With the information on the proficient utilisation of tower cranes, site managers will actually be able to achieve a quicker speed of construction, manpower reduction, reduced concrete wastage, and timely completion of projects.

As far as site management and site layout skills are concerned, site managers will find this study helpful in knowing how to choose tower cranes during the design and construction phases of a project. Their insightful abilities will be improved to cover the utility of the selected tower cranes. They will actually want to decide if the tower crane can meet the construction programme in terms of capacity and production rates. The effect of the selected tower cranes on the structural and architectural design, and lastly, the expense of operating the selected tower cranes. Third, the productive utilisation of tower cranes may once in a while require the utilisation of double tower cranes. Subsequently, site managers ought to not exclusively know about this reality but ought to look into the framework and related to the utilisation of double tower cranes. An illustration of such a precautionary measure is the overlapping work zones that result from the utilisation of double tower cranes.

### 5.2 Limitations and future studies

The study is restricted as far as setting and strategy. Relevantly, the discoveries in this study might be summed up as the Nigerian construction sector dependent on the significance of Lagos state to the country. Be that as it may, the discoveries are restricted to Nigeria and ought to be stretched out warily to different climes. Methodically, predispositions related to the quantitative examination might influence the dependability of the discoveries made by this exploration. Future investigations are urged to use a mixed method case study to develop this exploration. It would likewise be intriguing if future examinations would research and foster a balanced workload schedule for double tower cranes. Factors affecting tower crane relocation as well as evacuation strategies and issues related to the expulsion of tower cranes are significant regions that should be considered in later examinations.

## 6. CONCLUSION

Beyond tower crane location optimization, this study has set up that the effective utilisation of tower cranes begins with tower crane load and location contemplation. Basically, precast materials like blocks, bricks, precast façade, and concrete are to be considered as loads to be lifted with tower cranes. Other significant materials, like HVAC installations and formworks, ought to be lifted with tower cranes. Considerations for locating tower cranes should adhere strictly to tower crane setups, load type, and load quantity. Be that as it may, the principal standard to be considered is the site limitations. Without this thought, the tower crane location will become risky. As the functioning spaces are needed for the tower crane, the creation of a tower crane safety zone and determination of the tower crane coverage area will be hard to accomplish.

This study has additionally established that between tower crane load and location contemplations, selection parameters, configurations, and combinations of tower cranes should be focused on. Building height, operators' cost, cost of support system, soil condition, breakdown cycle and repair time are parameters that must be thought of while choosing tower cranes for a project. The significance of tower crane setups has not been linked, despite the fact that the safe and optimal utilisation of the tower crane is dependent on its design. In light of the discoveries made in this study, it is additionally reasoned that a double tower crane ought to be thought of while making arrangements for the effective utilisation of tower cranes.

This study has added to knowledge by introducing the techniques guiding the location of tower cranes on construction sites. The study found site constraints as the significant concentration in tower crane locations. This gives a more profound understanding of tower crane location and clarifies why safety and cost ought not to be the focal point of tower crane location optimization. Moreover, this study has featured the various kinds of loads and projects for which tower cranes ought to be considered. Knowledge of tower crane choice boundaries has been significantly enhanced by this study.

## REFERENCES


Abdelmegid, M. A., Shawki, K. M., and Abdel-Khalek, H. (2015). GA optimization model for solving tower crane location problem in construction sites. Alexandria Engineering Journal, 54(3), 519-526.

Abdi, H. (2007). Z-scores. Encyclopedia of measurement and statistics, 3, 1055-1058.

Al Hattab, M., Zankoul, E., and Hamzeh, F. (2014). Optimizing joint operation of two tower cranes through look-ahead planning and process simulation. In Proceedings 22nd Annual Conference of the International Group for Lean Construction.

Al Hattab, M., Zankoul, E., and Hamzeh, F. R. (2017). Near-real-time optimization of overlapping tower crane operations: a model and case study. Journal of Computing in Civil Engineering, 31(4), 05017001.

Bamfo-Agyei, E., and Atepor, L. (2017, July). Assessing the Safety Use of Tower Cranes on Construction Sites in Central Region of Ghana. In International Conference on Applied Human Factors and Ergonomics (pp. 486-496). Springer, Cham.

Briskorn, D., and Dienstknecht, M. (2019). Mixed-integer programming models for tower crane selection and positioning with respect to mutual interference. European Journal of Operational Research, 273(1), 160-174.

Danel, T.; Lafhaj, Z.; Puppala, A.; Lienard, S.; Richard, P. Proposal for Tower Crane Productivity Indicators Based on Data Analysis in the Era of Construction 4.0. Buildings 2021, 11, 21. https://doi.org/10.3390/buildings11010021

Dasović, B., and Klanšek, U. (2021, December). Comparison of spreadsheet-based optimization tools applied to construction site layout problem. In IOP Conference Series: Materials Science and Engineering (Vol. 1209, No. 1, p. 012010). IOP Publishing.

Dasović, B., Galić, M., and Klanšek, U. (2019). Active BIM approach to optimize work facilities and tower crane locations on construction sites with repetitive operations. Buildings, 9(1), 21.

Dasović, B., Galić, M., and Klanšek, U. (2020). A survey on integration of optimization and project management tools for sustainable construction scheduling. Sustainability, 12(8), 3405.

Fasih, S. M., Mohamed, Z., Husain, A. R., Ramli, L., Abdullahi, A. M., and Anjum, W. (2020). Payload swing control of a tower crane using a neural network–based input shaper. Measurement and Control, 53(7-8), 1171-1182.

Huang, C., Li, R., Fu, Y., and Ireland, V. (2019). Optimal Selection and Location of Tower Crane for the Construction of Prefabricated Buildings with Different Prefabrication Ratios. Journal of Engineering Science and Technology Review, 12(6).

Hyun, H., Park, M., Lee, D., and Lee, J. (2021). Tower crane location optimization for heavy unit lifting in high-rise modular construction. Buildings, 11(3), 121.

Jeong, K., Yun, K., and Lee, D. (2021). Study on Automatic Arrangement Algorithm for Tower Cranes with Applying Lifting Limit Axis. Turkish Journal of Computer and Mathematics Education, 12(6), 418 - 412

Jia, J., and Wan, Y. (2016, March). Light-weight design of tower crane boom structure based on multi-objective optimization. In International Conference on Mechanical Science and Engineering. Qingdao: Atlantis Press (pp. 1-6).

Jiang, L., Zhao, T., Zhang, W., and Hu, J. (2021). System hazard analysis of tower crane in different phases on construction site. Advances in civil engineering, 2021.

Jiang, T. (2020, July). Safety risk analysis and control of tower crane. In IOP Conference Series: Earth and Environmental Science (Vol. 546, No. 4, p. 042070). IOP Publishing.

Kaveh, A., and Vazirinia, Y. (2018). Optimization of tower crane location and material quantity between supply and demand points: A comparative study. Periodica Polytechnica Civil Engineering, 62(3), 732-745.

Kaveh, A., and Vazirinia, Y. (2020). An upgraded sine cosine algorithm for tower crane selection and layout problem. Periodica Polytechnica Civil Engineering, 64(2), 325-343.

Kim, J. Y., and Kim, G. H. (2020). Importance Ranking of Accident Factors of Construction Tower Crane by AHP Technique. Journal of Building Construction and Planning Research, 8(4), 237-244.

Li, R., Fu, Y., Liu, G., Mao, C., and Xu, P. (2018). An algorithm for optimizing the location of attached tower crane and material supply point with BIM. In ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction (Vol. 35, pp. 1-8). IAARC Publications.

Lingard, H., Cooke, T., Zelic, G., and Harley, J. (2021). A qualitative analysis of crane safety incident causation in the Australian construction industry. Safety Science, 133, 105028.

Marzouk, M., and Abubakr, A. (2016). Decision support for tower crane selection with building information models and genetic algorithms. Automation in Construction, 61, 1-15.

Moussavi Nadoushani, Z. S., Hammad, A. W., and Akbarnezhad, A. (2018). Closure to "Location Optimization of Tower Crane and Allocation of Material Supply Points in a Construction Site Considering Operating and Rental Costs. Journal of Construction Engineering and Management, 144(11), 07018002.

Nayal, D., Paul, V. K, and Kumar, K. (2020). Selection of Tower Crane using Multi-Criteria Decision-Making Techniques. International Journal of Engineering Research and Technology (IJERT), 9(5), 31 – 35.

Sadeghi, S., Soltanmohammadlou, N., and Rahnamayiezekavat, P. (2021). A systematic review of scholarly works addressing crane safety requirements. Safety Science, 133, 105002.

Shapira, A., and Ben-David, A. (2017). Characteristics of equipment planning for multi-crane building construction sites. Buildings, 7(3), 81.

Shin, I. J. (2015). Factors that affect safety of tower crane installation/dismantling in construction industry. Safety science, 72, 379-390.

Trevino, C., and Abdel-Raheem, M. A (2017). Modified ant colony optimization method for solving the single tower crane allocation problem.

Wang, R. D., Zayed, T., Wei. P., Zheng, S., and Tariq, S. (2021). A system boundary-based critical review on crane selection in building construction. Automation in Construction, 123 (2021) 103520

Wu, K., and Garcia de Soto, B. (2020). Spatiotemporal Modeling of Lifting Task Scheduling for Tower Cranes with a Tabu Search and 4-D Simulation. Frontiers in Built Environment, 6, 79.

Yao, G., Li, H., Yang, Y., and Pu, W. (2019). Seismic responses and dynamic characteristics of boom tower crane basing on measured strong earthquake excitation. Journal of Vibroengineering, 21(1), 154-169.

Yao, G., Xu, C., Yang, Y., Wang, M., Zhang, M., and Thabeet, A. (2018). Working Mechanism of a High-performance Tower Crane Attached to Wall Joints. Journal of Engineering Science and Technology Review, 11(1).

Zhou, W., Zhao, T., Liu, W., and Tang, J. (2018). Tower crane safety on construction sites: A complex sociotechnical system perspective. Safety science, 109, 95-108.