Development of a Framework for the Application of Project Management Tools in High-Rise Building Production in Lagos State, Nigeria

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Abstract

High-rise building (HRB) production in Lagos State, Nigeria, continues to experience persistent delays, cost overruns, and risk-related inefficiencies despite the increasing adoption of project management tools. This study develops an integrated framework for optimizing the application of project management tools to enhance performance outcomes in HRB construction. The research is grounded in Social Cognitive Theory and the Unified Theory of Acceptance and Use of Technology (UTAUT), providing a behavioral and technological adoption lens for evaluating tool effectiveness.

A mixed-methods research design was adopted, combining structured questionnaires, semi-structured interviews, and case studies. Data were collected from 224 building professionals operating in Victoria Island and Ikoyi, with 208 valid responses analyzed. Using a five-point Likert scale, data were examined through Relative Importance Index (RII), correlation analysis, and multiple regression modelling.

The findings indicate significant positive relationships between key project management variables—cost, time, and scope—and project performance in HRB production. Cost demonstrated a strong positive correlation with performance ($r = 0.52$), accounting for 27% of performance variance. Time ($r = 0.441$) and scope ($r = 0.717$) also exhibited statistically significant correlations. Multiple linear regression analysis revealed that these variables collectively explained 57.1% of the variance in project performance ($r = 0.756$, $p < 0.05$).

The study further establishes statistically significant differences in the effectiveness, deficiencies, and operational characteristics of project management tools applied in HRB construction. These differences influence production outcomes in distinct ways, underscoring the strategic importance of tool selection and contextual adaptation in high-rise construction environments.

Based on empirical findings, the study proposes a conceptual framework integrating Lean Construction, Building Information Modelling (BIM), and Earned Value

Management (EVM) to strengthen stakeholder engagement, risk management, decision-making processes, and performance monitoring. The framework provides a structured pathway for improving cost efficiency, schedule adherence, and risk mitigation in HRB projects within emerging urban economies.

This research contributes to construction management theory and practice by linking technology adoption behavior with project performance optimization and recommends institutional and policy support to enhance the implementation of structured project management frameworks in Lagos State.

Keywords

High-rise building construction; project management tools; construction project performance; cost overrun; schedule delay; risk management; Lean Construction; Building Information Modelling (BIM); Earned Value Management; Lagos State; Nigeria; construction management framework.

DECLARATION

I hereby declare that this research work, 'Development of a Framework for Use of Project Management Tools on High-Rise Building Production in Lagos State, Nigeria,' is an original product of my efforts, undertaken under the supervision of Bldr. Prof. Uche Ikechukwu and Arc. Prof. I. Onyegiri.

This work has not been previously submitted for any academic degree or certificate. All sources have been properly cited and acknowledged.

No part of this work may be reproduced or distributed without my explicit consent.

AMANZE, IKECHUKWU UCHENNA

18/ Ph.D/ 11362

CERTIFICATION

This is to certify that this project titled 'Developing Framework for Use of Project Management Tools on High-Rise Building Production in Lagos State, Nigeria, by **AMANZE, IKECHUKWU UCHENNA** has been carefully read, corrected and satisfactorily approved as requirement for the award of Doctor of Philosophy Degree (Ph.D) in Construction Management, Department of Building, Faculty of Environmental Sciences, Imo State University, Owerri.

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DEDICATION

This dissertation is dedicated to God Almighty.

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God bless you all.

TABLE OF CONTENT

CHAPTER FIVE

LIST OF TABLE PAGE

LIST OF FIGURES

ABSTRACT

This study aims to develop a framework for optimizing project management tools to manage delays, cost overruns, and risks in high-rise building (HRB) production in Lagos State, Nigeria. Grounded in Social Cognitive Theory and Unified Theory of Acceptance and Use of Technology. Employing a mixed-methods approach, the research involved surveys, interviews, and case studies with a sample of 224 building professionals in Victoria Island (VI) and Ikoyi; data analysis was based on 208 completed questionnaires. Using a five-point Likert scale, the data were analyzed with statistical tools including bar charts, pie charts, Relative Importance Index (RII), and various regression models to test hypotheses. The findings revealed significant relationships between performance and project management factors such as cost, time, and scope, indicating cost had a strong positive correlation with performance ($r = 0.52$), influencing 27% of the performance variance. Time and scope also correlated positively with performance ($r = 0.441$ and $r = 0.717$, respectively). Multiple linear regression confirmed that these factors collectively explained 57.1% of performance variance with strong positive correlation, $r = 0.756$. The research identified significant differences in the effectiveness of various project management tools for HRB production, with statistically significant results ($p < 0.05$) distinguishing these tools from each other and concluding that performance among project management tools differ significantly, impacting production processes uniquely. Also, the study concludes that the deficiencies of the project management tools used for HRB production in Lagos State differ significantly from each other. This research also revealed significant differences in the characteristics of various project management tools employed in HRB production and that these distinctive characteristics have varying effects on the production process, highlighting the importance of tool selection in the context of HRB construction. The study recommends critical success factors like stakeholder engagement and risk management, proposing a conceptual framework integrating tools such as Lean Construction, Building Information Modelling, and Earned Value Management to enhance collaboration and decision-making, ultimately reducing project uncertainties. The research contributes significantly to project management knowledge and suggests that stakeholder and government support is vital in implementing the proposed framework for more efficient and cost-effective HRB projects in Lagos State.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

In history, mankind has been striving for something more perfect, more ambitious, erecting ever higher and more sophisticated buildings like high-rise buildings (HRBs). HRBs are being built in connection with the growing population of cities and lack of land. As a rule, these are admired projects of special architectural significance, reflecting the state of the scientific and technical process, innovative technologies in construction. Tall buildings have features that significantly distinguish them from ordinary buildings.

According to the Lagos State Urban and Regional Planning and Development (URPD) Law 2010, any building with a minimum of five floors is considered as a HRB.

In Nigeria, a HRB is typically defined based on its height and the number of floors (Milosevic et al, 2006). However, in Lagos State, Nigeria, the definition of a HRB is specific and based on floor count.

Generally, HRBs range from 35-100m in height, while buildings exceeding 100m are classified as skyscrapers. Skyscrapers surpassing 300m are further categorized as super-high skyscrapers (Infoplease Encyclopedia, 2025).

HRBs play an integral role in meeting the country's housing needs and supporting urban development, particularly in major cities like Lagos.

The uniqueness of new HRB construction projects and their increasing complexity make them highly challenging. Hence it is very challenging to control the cost, schedule, safety and quality of construction. This situation becomes even more complicated due to various additional factors, including space constraints, safety regulations, and coordination requirements. Hence, managing complex construction projects is essential for ensuring success and avoiding potential pitfalls. (Meredith & Mantel, 2018; Lafhaj, Z., Rebai, S., AlBalkhy, W., Hamdi, O., Mossman, A., & Alves Da Costa, A, 2024).

The efforts to increase the probability of a HRB project completion, to implement it within the shortest possible period, in the top quality and with the lowest costs together with elimination of any other possible risks have led to development of a number of project management PM tools. From wider perspective, it is possible to obtain a detailed knowledge of (PM) tools, not only in literary sources focused on project management (Project Management Institute, 2021), but also in literary sources focused on other connected disciplines as risk management (Kharal, 2024), change management (Kumarasamy, S., Selvanathan, S. P., & Ghazali, M. F., 2025), Strategic management (Mark, S., & Situm, M, 2024) and logistics management (Liu, C., & Ma, T, 2022).

Project management (PM) tools have been developed one by one, and they are subject matters of interest of both the theory and practice of PM, where they are fine-tuned and modified, and new tools are created. In view of the continuous process of changes, it is not possible to provide an exhaustive list of PM tools, but it is possible to mention the best-known and most widespread ones. These tools specialize in various project management areas. While some of them are only used in some phases of the project life cycle, others are used in the whole course of project implementation (Project Management Institute, 2022). The important project management tools include, among others, the Triple Constraint of Project, which represents management of the three basic elements affecting the success or failure of a project: the project scope, time and cost. There are numerous tools that are utilized, namely; the project plan, complimentary plans of the project, meeting and reporting structures, pre-agreed on performance standards, project and milestones schedules, progress reporting templates, computers and software programs used for effective delivery, and the list goes on (William Malsam , 2023). Literature research records that project managers find that what determines the success of their projects is not merely correct sequencing of a critical series of activities, but the prioritizing of resources across the portfolio of multi-programs (Milosevic & Srivannaboon, 2006; Mishra, K 2020). Prioritization is more difficult for large projects of varying sizes and urgencies. The resultant experiential effect is the indispensability of relevant project management tools that can accommodate the project driven metaphor and a resource-based metaphor simultaneously. There is a need for tools and techniques that may help with correct prioritization of these critical series of activities for proper project implementation.

Nigeria's rapid urbanization and population growth have driven the demand for HRBs to accommodate the increasing population and optimize land use. While Lagos, Abuja, and Eko Atlantic have seen concentrated high-rise development, other cities are also witnessing growth in vertical structures (URPD Law, 2010)

Therefore, this present study purports to develop a framework that will guide the project manager in the selection of proper PM tools for correct prioritization of critical activities and prediction of risk in HRB project implementation.

1.2 STATEMENT OF THE PROBLEM

HRB construction projects in Lagos State, Nigeria, have consistently fallen short of performance expectations regarding duration, cost, and safety (Eli, 2023). The complexities and uncertainties inherent in these projects necessitate innovative solutions and continuous problem-solving. Despite the increasing uncertainty and risk involved in HRB construction, the Nigerian construction industry, particularly in Lagos State, still relies heavily on traditional deterministic and probabilistic scheduling methods such as Gantt charts, Critical Path Method, and Project Evaluation and Review Techniques (PERT), as well as software like MS Project and Primavera (Ahuja et al., 2020; Liu *et al*., 2020). However, these methods have limitations in capturing the complexities and uncertainties inherent in HRB construction in the Lagos State context, where projects are often characterized by unique environmental, social, and economic challenges (Zhang et al., 2020). Furthermore, the plethora of project management tools available in the market, coupled with the lack of awareness and inadequate utilization of sophisticated software and technologies, has led to difficulties in selecting suitable tools for HRB projects in Lagos State (Asadi et al., 2021). This has resulted in unsatisfactory outcomes such as time and cost overruns, safety risks, and reduced quality, ultimately eroding stakeholder confidence, increasing regulatory scrutiny, reducing competitiveness, and delaying economic growth in the region.

The study therefore is aimed at developing a framework that could be used to properly manage these PM Tools for HRBs in Ikoyi and Victoria Island, Lagos State, Nigeria, with a view to helping project managers avert the menace of time and cost overrun as well as risks in HRB production.

1.3 AIM AND OBJECTIVES OF THE STUDY

1.3.1 Aim of the Study

The study aimed to develop a framework for effective use of project management tools in high-rise building production in Lagos state, Nigeria, thereby minimizing delays, cost overruns, and risks in HRB production.

1.3.2 Objectives of the Study

In order to achieve the aim stated above, the following specific objectives were utilized to:

i. investigate how project management constraints (including cost, time, and scope) affect the performance of high-rise building (HRB) projects in Lagos State;
ii. examine the characteristics of different project management tools for HRB production in Lagos State.
iii. evaluate the performance of different project management tools for HRB production in Lagos State.
iv. assess the deficiencies of the project management tools for high-rise buildings production in Lagos State; and
v. assess the construction technology tools that can help eliminate challenges in HRB production in Lagos state.

1.4 RESEARCH QUESTION AND HYPOTHESIS

1.4.1 Research Questions

The research questions were as follows:

i. How do project management constraints (cost, time, and scope) impact the performance outcomes of HRB production projects in Lagos State?

ii. What are the differences in the performance amongst different project management tools for HRB production in Lagos State?

iii. To what extent are the deficiencies amongst the project management tools for high-rise buildings production in Lagos State?

iv. To what extent can the construction technologies tools that can help eliminate challenges in HRB production in Lagos state?

v. What levels are the characteristics for effective management tools in the HRB production?

1.4.2 Research Hypotheses

H_{01}: the project management constraints, including cost, time, and scope, have no significantly influence on the performance of HRB production projects in Lagos.

H_{02}: there is no significant difference in the performance of different project management tools for HRB production in Lagos State.

H_{03}: the deficiencies of the various project management tools used for high-rise buildings production in Lagos State do not differ significantly from each other.

H_{04}: there is no significant difference amongst the performances of the technologies that can help eliminate challenges in HRB production in Lagos state.

H_{05}: characteristics of the various project management tools do not vary significantly in their effect on the production of high-rise building in the area.

1.5 SCOPE OF THE STUDY

1.5.1 Delimitation of the study

The study focused on the development of framework for effective use of project management tools on High-rise building production in Lagos state. It was carried out on buildings between seven (7) to ten (10) floors only in the Victoria Island and Ikoyi, both in Lagos state.

However, for the assessment of the impact of performance on other project management constraints the study focused on buildings from seven (7) floors and above.

The study is limited to the four major management challenges which include; performance, cost, time and scope.

The characteristics of the project management tools is limited to those found on the literature.

Again, in evaluating the performance of project management tools for HRB production in Lagos State, only the ones which were used in the completion of the projects in the study areas were examined.

Furthermore, the deficiencies of those tools as regards to why they do not offer the required result in curbing cost and time overrun, predicting risk and assuring quality were assessed.

Finally, only the tested and trusted technologies and software found in literature and companies reports were used in the development of framework.

1.5.2 Area of the Study

This study is carried out in the Victoria Island (VI) and Ikoyi, Lagos state, Nigeria. Lagos State lies exactly on Latitude 6°27′11″ N and Longitude 3°23′45″E.It lies in the South- Western Nigeria on the Atlantic coast in the Gulf of Guinea. Lagos State has an estimated population of about 15,945,912 (AAI, 2023). Victoria Island is one of the communities in Eti-Osa local government area (LGA) of Lagos, Nigeria (Figure 1.0). It is geographically situated along latitudes 6°23′N and 6°41′Nand longitudes 2°42′E and 3°42′E. It is bounded in the north by Ikoyi, the east by Lekki, the west by Apapa and the south by Atlantic Ocean, as shown in figure 1.0 below.

VI has a population of about 283,791 (AAI, 2023). The latitudinal location of VI and its environs enjoy the characteristics of the West African monsoonal climate, marked by distinct seasonal shift in the wind pattern. The rainfall pattern in the study area can be explained in terms of the movement of the Inter Tropical Convergence Zone (ITCZ). The average monthly rainfall is about 151.83mm, with a high percentage of falling between the months of April and October. During the rainy season, the lowest monthly rainfall is December, while the highest monthly rainfall is June, July, September and October. The entire area has “light” surface in terms of degree of roughness of terrain and slopes. The terrain could be described as almost flat. However, there are patches of elevated areas and depressions. The geological history accounts for the almost flat terrain, where most land areas are between 18 and 25 meters above the sea level.

VI and the entire axis are surrounded by Atlantic Ocean. Expectedly, the area by the various water bodies is low lying. The water bodies are key ecological elements in the area, with great impacts on temperature and humidity. The mass of water around the town is believed to have also influenced the pattern of growth on VI and the adjoining development Water Bodies. It enjoys a daily temperature of about 27 °C because of the influence of the two air masses – the maritime south-west monsoon winds and the continental north-east dry winds from the continental interior. Victoria Island is one of the affluent neighborhoods in Lagos. Real estate investment in VI alone is worth over $12 bn (Lagos State Government, 2017).

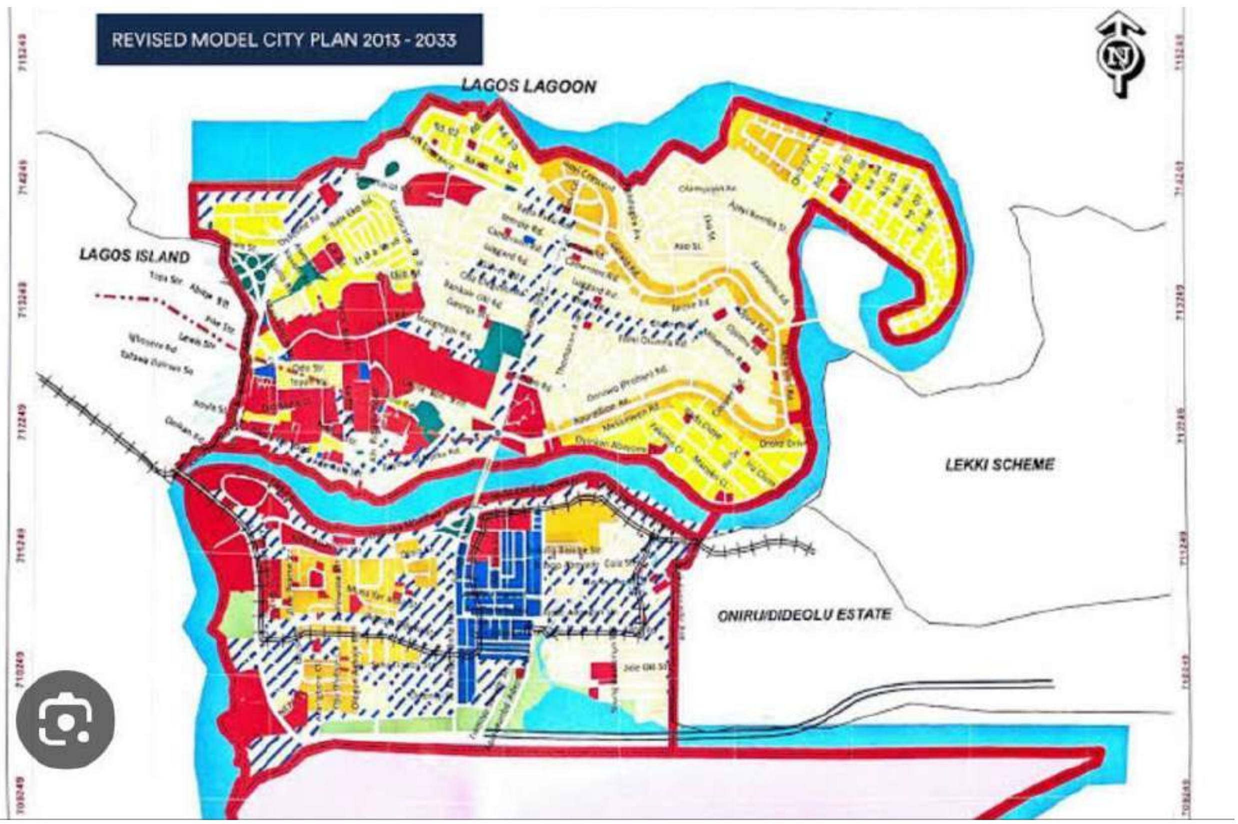


Figure 1.0: Victoria Island in Eti-Osa LGA Lagos, Nigeria.
Source: *Lagos State Government, Ministry of Physical Planning (2023)*

Relatively, Ikoyi is the most affluent neighborhood of Lagos, located in Eti-Osa local government area. it lies to the Northeast of Obalende and adjoins Lagos Island to the west and edge of Lagos lagoon. Ikoyi has an estimated population of 118,000 (AAI, 2023). Ikoyi is one of the regions with the highest amount of rainfall in Lagos, with rains often exceeding 3000mm every year. Ikoyi area of Lagos is located near the eastern margin of the Nigerian sector of the Benin basin, within the Western Nigeria coastal zone which consists largely of coastal creeks and lagoons developed by barrier beaches associated with sand deposition underlain by recent deposits which vary from the littoral and lagoon sediments to the coastal belt and alluvial deposits of the major rivers (Pugh, 1954). It forms part of the Lagos lagoon system known to be the largest of the four Lagoon system of the Gulf of Guinea Coast (Adepelumi and Olorunfemi, 2000).

Geologically, the study areas is a sedimentary basin which falls within the coastal plain sands of the Benin formation which was latter overlain by alluvial deposits. Stratigraphy of the eastern Benin Basin has been discussed by various workers and several classification schemes have been proposed. These notably include those of Jones and Hockey (1964); Omatsola and Adegoke (1981) and Billman (1992). Deposition of Cretaceous sequence in the eastern Dahomey basin began with the Abeokuta Group, consisting of the Ise, Afowo and Araromi Formations. Tertiary sequence includes the ewekoro, akinbo, oshosun, ilaro and coastal plain sands (Benin) Formations (Omatsola and Adegoke, 1981).

The Quaternary sequence in the eastern Dahomey basin is the Coastal Plain Sands and recent littoral alluvium which consists of poorly sorted sands with lenses of clays. The sands are in parts cross bedded and display continental characteristics. However, lithostratigraphic information from boreholes in and around Lekki-Ikoyi area reveals that typical section of the stratigraphy consists of unconsolidated dry and wet sand, and organic clay deposit. The deposits are sometimes inter-bedded in places with sandy-clay or clayey-sand and mud with occasional varying proportion of vegetable remains and peat. The environment of deposition of these sediments was suggested to be near-shore littoral and lagoonal (Longe et al, 1987).

The Victoria Island and Ikoyi were selected for this study because they are homes for High-rise buildings. The buildings exceeding 7 floors in victoria Island is about 76 in number, while the buildings between 7-10 floors are about 41. In a related development, Ikoyi has up to 38 high-rise building structures, with 17 between 7-10 floors (field survey, 2023).

1.6 LIMITATION OF THE STUDY

These limitations provide insights into the study's boundaries and areas where further research or improvements are needed. Here are some potential limitations:

Sample Size and Generalizability: The study may have a limited sample size due to practical constraints (e.g., time, resources, access to participants).

Findings based on a small sample might not be fully representative of the entire high-rise building production context in Lagos State.

Researchers should acknowledge this limitation and consider the implications when generalizing the results.

Context-Specific Findings: The study focuses on Lagos State, which has its unique characteristics, regulations, and challenges. Findings may not directly apply to other regions or countries with different contexts.

Data Collection Methods: The study relied on specific data collection methods (e.g., surveys, interviews, case studies) and each method has inherent limitations (e.g., response bias, recall bias, subjectivity).

Time Constraints: Time limitations impacted the depth and breadth of the study.

The time might not be sufficient to explore all relevant aspects thoroughly.

Future studies could allocate more time to comprehensive data collection and analysis.

Resource Constraints: Limited resources such as financial, human and technological also affected the study's scope. The research was also faced with challenges in accessing specific tools, technologies and experts.

Assumptions and Simplifications: The study made certain assumptions or simplifications to create the framework. These assumptions might not fully capture the complexities of real-world high-rise building projects.

External Factors:

High-rise building production is influenced by external factors (e.g., economic conditions, political stability, market trends).

The study might not account for all external variables.

Dynamic Nature of Technology:

Project management tools and technologies evolve over time. The study’s framework might become outdated as new tools emerge. Hence there is need for continuous adaptation and updates.

Human Factors:

The study might not fully address human behaviour, communication, and collaboration. Project success depends not only on tools but also on how people use them. The interplay between technology and human factors where fully captured in the course of this study.

Scope of Recommendations: The study proposes a framework, but its implementation and effectiveness depend on various factors.

Limitations related to the practical application of the framework should be acknowledged.

1.7 SIGNIFICANCE OF THE STUDY

The significance of this study lies in its comprehensive approach to addressing the challenges in high-rise building (HRB) production in Lagos State, Nigeria. By identifying the challenges, assessing the characteristics of different management tools, evaluating their performance, and modeling scenarios to proactively manage risks, this study provides a holistic understanding of the complexities involved in HRB production.

The significance for this study is multifaceted thus:

- ❖ Research Gap: The study reports a significant research gap in the existing literature on HRB production, which has largely focused on technical aspects rather than management tools and risk management.
- ❖ Human-Centric Insights: By acknowledging the limitations and challenges posed by human factors, such as cognitive biases, communication breakdowns, and team dynamics, this study provides valuable insights for developing management tools and strategies that can mitigate these issues and improve project performance.

- Practical Application: The study's focus on HRB production in Lagos State, Nigeria, provides a practical context for understanding the challenges and developing effective management tools.

- Stakeholder Benefits: The study's findings will benefit various stakeholders, including project managers, clients, contractors, and policymakers, by providing them with effective management tools and risk management strategies.

- Generalizability: While the study's findings may be generalizable to other contexts, including other cities in Nigeria and other developing countries, where HRB production is becoming increasingly common, it's essential to acknowledge the potential limitation posed by the sample size being drawn from only Lagos State.

This study's significance lies in its potential to contribute to the development of effective management tools and risk management strategies for HRB production, which will benefit various stakeholders and contribute to the advancement and expansion of the construction industry.

1.8 EXPLANATION OF THE KEY TERMS

1.8.1 Project management tools

PM tools are software created to assist the project teams in planning, organizing, coordinating, managing projects and providing a centralized platform for collaboration, tracking progress, and managing task. Helping also to achieve project goals within timelines and with scarce resources. Effective and efficient project management is crucial in today's dynamic business environment, and project management software offers a solution to most manual management challenges.

1.8.2 High rise building

Depending on the context and local regulations, the minimum height for a building to be considered a high-rise varies. Below are some common definitions:

Building Codes and Regulations:

In line with the 1968 Building Code, a structure is classified as a high-rise if it is at least 75 feet (22.86 meters) in height. This definition however can vary by region and more recent codes may have different criteria.

General Definition:

A HRB typically refers to a tall structure specifically designed for residential, commercial and industrial purposes.

It is an elevated construction that is over 75 feet tall, buildings between 7 and 10 floors, falls into the category of a HRB.

Additional Classifications:

Beyond the standard high-rise definition, there are further classifications:

Super-tall building: A building that reaches a height of 300 meters (984 feet) or taller.

Mega tall building: A building that surpasses 600 meters (1,968 feet) in height.

The opposite of high-rise is a low-rise building and in the middle are mid-rise buildings.

1.8.3 Low-rise building

Low-rise buildings (LRBs) are short buildings, which usually are up to five storey. These may or may not have elevators and are usually made up of only a few units.

1.8.4 Skyscraper

Generally, a skyscraper is a very tall HRB, spanning over 152 meters (500 feet) high. Most skyscrapers are built in urban areas such as cities, and they are very common in the central business district known as downtown areas of many large cities including New York City, Chicago, Sydney, Beijing, Berlin, London, Paris, Toronto, Moscow, Hong Kong and Tokyo.

1.8.5 Project Management Triangle

The project management triangle, also known as triple constraints or the iron triangle, visualizes the need to balance scope, cost, and time to achieve a high-quality final product. No single variable within this triangle can change without affecting the other two points. Project managers must navigate these constraints to keep projects on track.

1.8.6 Cost Performance Index (CPI) for project management.

Typically, within the framework of **earned value management (EVM)** are technique used to measure project performance. Calculating the CPI and SPI are part of this process.

CPI is a metric that enables the project managers assess the financial performance and efficiency of a project. Expressed as: (CPI)= EV/AC. Where:

- **Earned Value (EV)**: Earn Value (EV) = % of Completed Work at a time **x** Budget at Completion (BAC)
- **Actual Cost (AC)**: The total cost incurred to date.

1.8.6.1 Interpretation:

- ✧ CPI > 1.0 → The project is under budget (cost-efficient).
- ✧ CPI = 1.0 → The project is on budget.
- ✧ CPI < 1.0 → The project is over budget (cost overrun)

For CPI greater than 1 indicates that the project is under budget. An Example is project with a CPI of 1.1 implies that the project is 10% under budget. CPI thus helps project managers appreciate the cost performance, identify deviations from the baseline, and make informed decisions to keep the project financially efficient.

1.8.7 Schedule Performance Index (SPI): SPI similarly quantifies **schedule efficiency** by comparing the **earned value (EV)** to the **planned value (PV)** of a project. Expressed as SPI=EV/PV.

- **Planned Value (PV)**: Represents the planned progress at a specific point in time. It **reflects how much was expected to be accomplished.**

- **Earned Value (EV): The actual progress achieved. Ideally, EV aligns with PV, indicating on-schedule performance.**

Where: EV is the actual progress and PV is expected progress.

The SPI measures **scheduling efficiency** by comparing the **proportion of completed work** to the **scheduled work**. Thus, SPI focuses on the ratio of work done to planned work.

1.8.7.1 Interpretation:

- ✧ SPI > 1.0 → The project is ahead of schedule.
- ✧ SPI = 1.0 → The project is on schedule.
- ✧ SPI < 1.0 → The project is behind schedule (delayed)

1.8.8 Schedule Variance (SV):

- Schedule Variance (SV)**: The SV measures** deviation from the initial schedule **by comparing the** difference between Earned Value (EV) **and** Planned Value (PV)**.**
- **The SV is expressed as: SV = EV - PV**

1.8.8.1 Interpretation:

SV > 0: Ahead of schedule (earned value exceeds planned value).

SV = 0: On schedule (earned value matches planned value).

SV < 0: Behind schedule (earned value falls short of planned value).

Key Additions:

- SPI focuses on efficiency (work completed vs. scheduled work).
- SV assesses divergence (actual progress vs. planned progress).
- Both SPI and SV are essential tools for tracking project progress and ensuring timely delivery.
- CPI often confused with SPI; the CPI assesses cost efficiency.

Thus, tracking CPI, SPI, SV, CV and other EVM metrics is essential for effective project management.

CHAPTER TWO

LITERATURE REVIEW

2.1 CONCEPT LITERATURE

2.1.1 General overview of High-Rise Buildings

High-rise buildings are often noteworthy architectural projects that represent the status of the science and technology process, as well as novel construction methods, and are being built in response to increased populations of cities and a scarcity of land. Tall buildings have characteristics that distinguish them from other structures. These are well-known architectural designs that represent scientific and technical development while also reducing technology.

Tall buildings are built out of necessity as one of a wide range of tools to achieve high density development. They provide the opportunity to control urban sprawl with their relatively small foot print. Identifying what unique characteristics a tall building brings could be represented in the need for a particular built form- the concentration of activity-the proximity to important facilities for large numbers of people which is more than "image" and being a more sustainable form of development. Some appear to be opposed to tall buildings wherever they are located or whatever they look like. The positive and negative influences through development by high-rise towers and tall building could be evaluated within certain factors including (Social –Environmental –Economics-Emotional-Safety (Fire-Earthquakes).

Tall buildings have been blamed for crime, mental breakdowns, the generation of urban pathologist-they deform the quality, the function, by overloading the infrastructure and the public realm of the streets that contain them. Criticizing the construction of High-rise building as being about power prestige than efficient development, some critics say super-tall buildings are too hard and expensive to build. Addressing the kind of risks that a tall structure is likely to encounter in its, life time, risks of safety problems are usually associated with unknown disasters like for example blocking fire escape (NFPA, 2006).

High-rise buildings bring impacts at strategic and local levels. The huge people's load of a high building, particularly at peak times, may overload the city's infrastructure - its public transport, roads and utilities. The size of a building has important direct influences on our emotional response. More and more planners are being asked to consider streets-cape in addressing a community's quality of life; streets-capes play a central role in place making and providing spaces for social interaction. Understanding their proper design and the impact of that design is essential in planning healthy and vibrant communities (Bekkering et al, 1997).
Shadow restrictions are designed to limit the height of buildings so as to ensure sufficient sunlight in the city.

Buildings that reach new heights pose numerous engineering and technological problems relating to such issues as building a sufficiently strong foundation, ventilation, heating, cooling, lighting, transportation (elevators, stairs, parking), communication, electrical power, plumbing, wind resistance, structural integrity, fire protection and building security (Glaeser and Jesse, 2001). There also is a host of public issues connected with the increases in employment density brought about by tall structures, such as transportation congestion and environmental concerns (Sukkoo, 2002).

2.1.2 Project Management

The Project Management (PM) has recently become a current subject in most organizations ranging from IT, manufacturing, Health and construction. PM is a management tools used universally to achieve optimal performance in an organization. Literature revealed that PM practice has been used extensively in organizations in the developed countries; however, the adoption of this practice has been limited in the developing countries (Olateju et al., 2011). Various definitions of PM have been proposed by different scholars. This study will adopt the following definition of Project Management.

• Project management is defined as “the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements. Project management is realized through the application and integration of the project management processes of initiating, planning, executing, monitoring and controlling and closing” (PMI, 2013).

• Project management is the application of methods, tools, techniques and competences to a project. Project management includes the integration of the various phases of the project life cycle. Project management is accomplished through processes” (ISO, 2012).

• OGC (2009) cited by Rehacek (2017) defined project management “as planning, delegating, monitoring and control of all aspects of the project and the motivation of those involved, to achieve the project objectives within the expected performance targets for time, cost, quality, scope, benefits and risks."

• The APM Body of Knowledge (APM BoK) defines project management as "the process by which projects are defined, planned, monitored, controlled and delivered so that agreed benefits are realized" (APMBOK, 2006).

The definition from PMI (2013), ISO (2012) and APMBOK (2006) emphasized on generic and practical aspect of PM and do not consider the triple constraint (cost, time and quality) in their definitions which is regarded in the literature as the key success factors that guides (Olateju et al., 2011) the project managers throughout the project life cycle.

The definition from OGC (2009) cited by Rehacek (2017) highlight these variables and mention also the PM process in which is also identified in other definitions. However, these are not the only criteria for project management success. As demonstrated in the literature, the concept of PM success has captured the attention of several scholars over the years and some do agree with the definition from OGC (2009) including the PM practitioners (Ika, 2009). This definition supports the concept of "iron triangle", though project success can be defined using these variables, however, does not make a perfect definition. Project success is vast from PM point of view. According to PM standard project must meet the three factors such as; cost, time and quality before it is considered as a successful project. These three variables are known as "irontriangle" (Pollack et al., 2018). However, there are a lot of doubt concerning "iron triangle" as many projects that are said to meet all these requirements stated in this principle (iron triangle) still experience project failure (Awwal, 2014), and do not satisfy the expected project outcome.

In order to give a more convincing definition to project management success, there is need to introduce one more factor to the iron triangle (Awwal, 2014), which is stakeholder satisfaction. Another limitation of this definition is that it did not mention PMTT which is considered by many authors (Olateju, et al., 2011) as one vital element used by modern organizations to implement their projects. The application of PMTT has been acknowledged as an effective strategy which would aid in improving project goals (Ayodele et al., 2015; Arnaboldi et al., 2004).

2.1.3 Tools and Techniques in Project Management

There are several project managements tools and techniques available in the market place and accessible to project managers. Most of them are used often in carrying out project management practice while some are not usually in use at all-time depending on the nature, type and size of the project. Although literature has pointed out the impact of these tools and techniques to project success, however, the most frequently mentioned ones in academic journals are discussed below:

2.1.3.1 Work Breakdown Structures

Work Breakdown Structure (WBS) is a hierarchical method that successively subdivides the work of the project into smaller detail. The WBS breaks the work into manageable work packages and checklists easier to manage, plan, control and allocate to specific individuals. It seeks to group similar tasks together to improve productivity and efficient use of resources. Cost-center costing is more effective using WBSs as they allow for maximum focus on specific sections of the project. Burke (2008) refers to the WBS as the backbone of the project.

The main components of the WBS are essentially the structure, methods of subdivision and numbering or coding system. The purpose of the WBS is to subdivide the scope of work into manageable work packages, this is not a straightforward task and many new project managers seek to avoid. The WBSs is a summation of work packages which comprise of activities and checklists. The WBS can best be defined as the map of the project (Gray & Larson, 2008) which ensures that all the work elements are identified. It helps integrate the project with the whole organization and thereby create a basis for control. It is essentially the deliverables beginning with the project that is divided into work packages divided according to the type of work at the most minimum sub-deliverable showing work progress, cost centers and responsibilities.

The project is one large final activity made up of work breakdown structures which are a summation of work packages. The work package can be represented in hierarchical format to emphasize the structure and the process of work breaking down. Work packages have the shortest duration or they are the minimum tasks or elements of the project with a definite start time and end time. At this point it is easier and more accurate to work out the costs, assign a specialized skill and monitor the progress of the execution. A work package manager therefore sees to the completion of the respective task within a specified time and budget according to customer expectations and technical specifications.

At pre-construction phase, the WBS provides accurate and detailed information as well as a cost analysis to the clients. It also aids in managing and implementing a project effectively and profitably at construction phase (Globerson et al., 2016). According to Kerzner (2003) “a WBS is a product-oriented family tree subdivision of the hardware, services, and data required to produce the end product”. The WBS is also seen as a deliverable-oriented grouping of the work included in a project that describes the entire scope of the project. Kerzner (2003) further stressed that the ‘family tree’ structure endeavors to grab the entire work of the project in an ordered manner into a task that is estimated as well as tracked.

It is an essential document that makes available the basis for managing and planning, project cost, resources, schedules and changes. The tree root is named by the name of the project, issue or opportunity to be looked into. Besides, the project management plan and project scope statement are the major contributors to developing a WBS, and it serves as a contributor to the main project management activities such as resource planning, risk management planning, activity definition, cost estimation and budgeting (Schaufelberger & Holm, 2017).

According to the PMI (2013), the scope baseline comprises the project document, for instance, a project statement of work and the WBS lexicon. The WBS lexicon comprises of comprehensive information about tasks, deliverables and planning information of every part of the WBS. The accompanying information is included in the WBS lexicon: constraints and assumptions, resources needed, benchmarks, schedule milestones, code of conduct identifier, work description, associated schedule activities, agreement information, responsible organization, quality requirement and technical references (Schaufelberger and Holm, 2017).

It is important to note that there is a difference between the Work Breakdown Sub-deliverable and a work package. A work breakdown sub-deliverable includes the outcomes of more than one work package and may encompass two or more departments, and as such may not have a duration of its own. Thus the work package comprises the most basic unit for planning, scheduling, and controlling of the project. Gray and Larson posit that the ideal work package within a WBS is characterized by;

- clearly defined work, what is to be done
- specified time of start and completion of task
- specified budget for the completion
- identified and specific resources required
- specific individual to oversee and control the package
- specified standard performance to be measured against

To gain effective and efficient usefulness of a breakdown structure depends on an effective coding system. The codes assist in the identification, defining and allocation of levels and elements, work packages and cost information in the WBS. The codes allow reports to be consolidated at any level in the structure. The WBS is best for design and build projects with tangible and measurable outcomes that can be decomposed to major deliverables, sub-deliverables and finally to work packages. By inference therefore there are certain projects that do not lend themselves to effective use of the WBS and coding because they are less tangible and more process oriented type projects in which the final project is a result of a series of steps, phases and plans culminating in an end product without measurable end results or deliverables.

2.1.3.2 Gantt Charts

This is a graphic presentation of the project execution activities depicted as a time scaled bar line. Burke (2008) refers to it as a scheduling tool where the time of each activity is represented as a horizontal bar with the length of the bar proportional to the duration of the proposed activity. The Gantt chart owes its origin to Henry Gantt in the early 1900s where it was used as a special project management tools. It was developed further in the aerospace projects of the 1950s and 1960s. It is believed that nearly all the project management tools and techniques used today were developed during the growth of the USA defense-aerospace industry. These include PERT and EV (Program evaluation and review technique and Earned value respectively).

A Gantt tool is an easy yet excellent program which allows for time, resource and cost analysis in one single spreadsheet. With the Gantt chart you can track up to eight tasks in one row and you can further create cost and resource analysis with a variety of summaries. With the modern use of Microsoft-Excel as an add on, the Gantt chart is pretty handy for the project planner. The advantages of the Gantt chart are numerous and can be listed as, namely; its ability to show activities, time scale for the project, start and finish dates for tasks or activities, actual activity progress, milestones, interdependency of the tasks and clearly stated resource requirements for the tasks.

According to Olawale and Sun (2015), project managers, especially those managing complex projects such as construction projects, must understand what activities need to be carried out in order to aid in the development of a project schedule. Behnam et al. (2016) state that a Gantt chart offers an adequate format for presenting information regarding project scheduling by listing all the project activities as well as their corresponding starting points and finish dates, claiming that the construction project is understood to be a multitask project and to appreciate the different stages of work, duration of activities and resource allocated to these activities. A Gantt chart must be used to display each task simultaneously in a calendar format.

However, Kumar and Chakraborty (2016) argued that a Gantt chart does not demonstrate the relationships that exist between each activity and it depends totally on a well-developed WBS that has been completed, and if there is any missing milestone or key activity, the Gantt chart will not identify it. Also, Olawale and Sun (2015) criticized this PMTT for not having the ability to accommodate as much information as it ought to, stressing that once the project durations
as well as an activity stretch beyond a page, the Gantt chart at this point starts to lose its performance. Literature has also asserted that a Gantt chart does not perform well with project triple constraint (time, cost and scope), adding that the project cost and project scope are not fully represented on the Gantt chart; and irrespective of how it is detailed, and it does not show the complete complexity of the task because its focus is on time.

Generally, all construction projects seem unique in nature, involve various phases, tasks, complex methods, project stakeholder and involve huge investment, therefore, the need for appropriate scheduling. Ogunde and Fagbenle (2013) claim that a well-scheduled, controlled, planned as well as carefully monitored construction project has influence on the project performance and success.

Studies show that not all project managers seem to employ planning tools in a construction project and the very few that employ planning tools, consider the Gantt chart because of its simplicity.

2.1.3.3 Critical Path Method

The critical path of a project is the path that determines the longest duration through the project network that it takes to execute the project from start to finish. Cain and Wong (2007) define it as the estimated project duration whose period equals the longest path through which the project network passes. If there are more than one such "longest paths" with equal value, all of them are critical paths for the said project. The use of this technique is to decide on the duration of the project because the critical path method (CPM). Hillier and Lieberman (2010) posit that the critical path is one of the routes through a project network following the arcs from the START to the FINISH node in a project. Project networks consists of activities to be completed in a particular sequence and are shown by the use of arrows to nodes (the activities to be completed).

Possible Routes for A Project Network: The critical path method shows the nodes or activities to be accomplished and the paths shown by arrows, some of which may be done simultaneously and others depend on the completion of the others. The duration is put as figures in the divers nodes, this represents the time which could be hours or days, or weeks or months or longer depending on the type of project. The project duration cannot be longer than the longest path, which is the critical path. In principle it can be performed sequentially without interruption; otherwise this would not be the longest path. In the critical path method therefore the FINISH or completion equals the length of this path.

The activities on this critical path are the bottlenecks or constraints to speedily executing the project. This tool is critical for effective project management, the critical path method therefore serves many critical functions in effectively executing a project, amongst which are, namely; the costing of the project is based on this path, the time estimation is based on this path. Any endeavours to crash the activity are based on the ability of the project manager to identify the number of activities that may be reduced to cut down on the time taken to complete the exercise. A trade-off is needed between the eventual cost and the cut in the time necessary for the completion of the project. Depending on the choices available to the project manager, crashing may be through; asking employees to work overtime, or employing extra temporary staff to expedite the work. Crashing of the activities at any level will give a combination of time and cost somewhere on the line segment as indicated in the theoretical graph below.

Relationship between Activity Cost, Crash Cost and Time Taken: The critical aspect of the critical path analysis is the ability of this method to assess the problems faced by the implementation of the project plan. There are essentially three sets of activities, the interdependent, the dependent and the independent activities. The dependent or sequential activities need to be completed in a sequence and their completion or commencement is dependent on the completion or the commencement of certain activities. Parallel activities are completed independent of the other activities as stand-alone in the process of execution. The CPM assists in identifying these different sets of activities and show their dependence and the duration therefore assisting in the proper estimation of the time required and the budget for the purpose. It is important to mention here that there are further tools and techniques available to the project manager to crash the activities to reduce the time and possibly cut costs. The manager has to choose the least expensive method of crashing the activities and he may use tools such as; marginal cost analysis or linear programming. The choice as to whether or not to crash the activities must be balanced between any possible negative effect on quality specifications as expected by the customer, the cost benefit to the project stakeholders and the time schedules for the use of the product should there be any such constraints or pressure.

The critical path method in a project, as pointed out earlier, is the most extended sequence of activities (that cannot be done in parallel) which decides how soon the project can be finished or delivered (Rolfe et al., 2016). This implies that activities within the critical path should be given more consideration as a slowdown in any of the activities will result in a deferral in the whole project accomplishment. Consequently, it is essential that the project manager identifies the activities that are on the critical path at all times. This is accomplished by deciding the early start time (EST) and the late start time (LST) of every activity. The contrast between the early start time and the late start time is the slack – the period in which either of the tasks in the project can be deferred without affecting the period of the entire project accomplishment (Nafkha & Wiliński, 2016).

Kumar and Chakraborty (2016) observed that the critical path method helps the project manager to allocate the time periods (in which a task can be finished) to every activity recognized in the project, then attempt to know the most early likely date that a task can commence and the latest likely date that a task can commence by doing backward-pass and forward-pass analyses. Sing et al. (2017) and Kumar and Chakraborty (2016) noted that construction companies in advanced countries appreciate the critical path method because it takes into consideration the limited resource when developing a project planning.

In another development, Hendriks et al. (2017) looked at the critical path method in private construction companies in a developed nation and emphasized that the level of usage is quite high as a result of activities that start and complete within the required time. In contrast, project managers in Nigerian indigenous construction companies seem to be unproductive as a result of their inability to allocate resources that will fit a specific activity as required, thus preventingthem from meeting the project standard. Ogunde et al. (2017) stated that not knowing how to adopt this tool also contributed to failure to meet deadlines and work within the required budget.

Cicmil et al. (2017) described these tools as an essential tool in construction projects, taking into account the numerous activities involved in construction work, and that each of the tasks must be given close attention in order to achieve a successful project outcome.

2.1.4.4 Project Risk Management

The risk is the unanticipated situations that are built-in in activities of humans, of which project management is not an exception. This might seem, by all means, to be a more extensive definition incorporating every human effort, with regards to project management. Risk can be explained as the uncertainties that may negatively affect the project by challenging the project's constraints or parameters. This can bring about the loss of work, time, cash or the project in general. In contrast, risk can impact on a project positively also: At the project level, this may be the development of new capabilities by the organization as a result of the project or unexpected uses for the project outcome. At the task level, an early finish may result in the opportunity for another activity to start early, or for the development of a better way of completing that task.

The exclusive nature of the project has made risk an important part which must be properly managed if the project is to be a success. The project manager's capacity to recognize, evaluate and manage project risk will profoundly affect the consequence of the project (Olateju et al., 2011). Moreover, project risk can shoot out from inside of the project: that is internal risks which are unpredictability related to the project cost, quality and time, or the external project risks, which are typically issues related to the environment. Besides, risk management could be prorated into four principal parts: risk register, risk responses, risk assessment and risk identification. This assists in the study by quantifying, identifying and looking for a way to manage the indicated risk (Olateju et al., 2011).

2.1.4.5 Earned Value Management

Earned value management (EVM) is recognized as a key project management tool that applies information that is based on project cost, work performance and schedules to establish the existing position of the project. It allows project managers to induce existing trends in order to make predictions of their possible final effects. This technique is cantered on a basic standard of project, however, is demonstrated to be beneficial in terms of cost control. EVM is established to give a better description of the time as well as the scheduling aspects of the project. EVM has been established to facilitate project or work progress control. It is employed for determining the status of the project as well as scaling of existing plan variation. Moreover, it gives room for the management to make suggestions on the ultimate effect of the entire project, taking into account the cost and project duration to an extent, and this is achieved via extrapolating the existing trends. This approach is considered simple and it has been known as a useful PM tool by government agencies and PM practitioners and been regarded as a standard in the field of project management (Heldman, 2018).

However, EVM poses practical problems to the project manager in terms of complex calculation. When complex activities that do not have a measurable or tangible result are estimated, there is that tendency for bias to set in. This becomes a challenge during the application of this tool (Olateju et al., 2011; Heldman, 2018). EVM is used in construction companies to monitor, control and direct project performance. It is used to manage scope change by allowing the tool to maintain the final cost of the construction project. It assists project managers to relate the activities that were initially planned with the activities that were actually earned and the actual amount spent on the work to determine whether the cost as well as the schedule performance meet the approved plan. EVM allows project managers in construction companies to define the actual work schedule for their numerous activities and also provides the essential data that aid in tracking performance and are capable of explaining the impact of the project to top management.

2.1.4.6 Business case

The Business Case allows the stakeholder in the organization to make decisions concerning the feasibility of the proposed project. The application of a Business Case is considered best practice all through the private and public construction industry. In most societies, there are laws that make it mandatory for the use of this sort of project management tool. For instance, Capital Planning and Investment of an organization needs some form of this project management tool (Business Case) for all construction work (Heldman, 2018). Before the development of these tools, a statement reflecting the business needs is necessary for the early presentation of the current project concept. This single document offers robust information used in justifying the decision for progression with the full Business Case development. Therefore, any decision made by the top management, stems from the review of the document that contends the business's needs (Kerzner, 2018). Furthermore, as soon as the business needs document is completed, approved by the governance body, and the authorization of the development of the business case is achieved, a full detailed Business Case is then developed (Kerzner, 2018).

Business Case according to Pospieszny et al. (2018) harmonizes together the entire outcome of all the essential findings as well as the analysis required to underpin the decision making in a manner that is transparent. Also, it is a key document essential for a proposed project solution and also encapsulates project objectives, specifics and key qualities of the implementation process (Heldman, 2018). In contrast, other scholars suggested that the Business Case is a business plan that has no capacity to guarantee project success. Also, in a situation where the plan is rigid, issues may arise that could influence the outcome of the project (Kerzner and Kerzner, 2017). Supporting this argument, Heldman (2018) added that high expectation from the Business Case could cause excessive spending in some other areas, for instance, staffing and stock. In the context of the construction project, the Business Case helps in presenting a viable proposed document containing the business needs in order to gain response from the decision maker on the best way of addressing these needs. The tool offers essential information for making business decisions in the construction industry. The Business Case provides vivid possible options, detailed analysis, and makes recommendation on potential options to be considered by the decision makers. The key advantages of this tool are that it gives room for the decision-making procedure to continue all through the project life- cycle (Heldman, 2018).

2.1.4.7 Project Network Diagram

Kumar and Chakraborty (2016) highlight that network diagram tools are vital PM instruments, which are utilized to demonstrate the sequence by which project activities are done. It is capable of demonstrating which tasks or activities in the project should be carried out before which, and how each task relies on the others.

Supporting the above assertion, Heeks and Stanforth (2014) claim that the network diagram is considered as a schematic representation of logical relationships or categorization of project tasks, adding that to use the project network diagram, it is essential to determine activity relationships. See **Figures 2.0 and 2.1 below**. Golini and Landoni (2014) illustrate the activities displayed in this PM tool, stating that "In this activity on the node graphic representation the notation used is that the center number in each node is the activity name (a number in this case) and the upper number in each node is the activity duration".

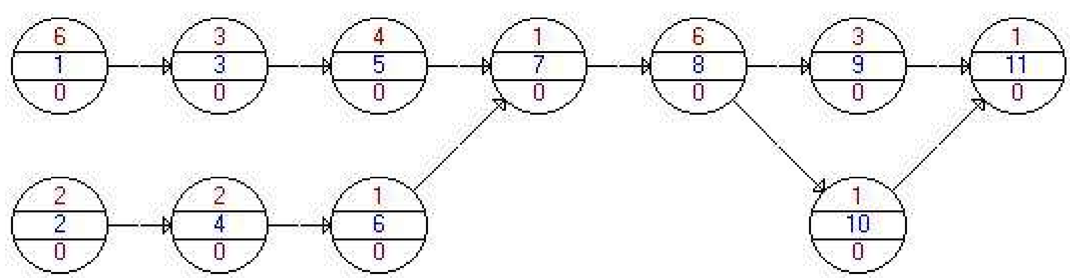


Figure 2.0 : Network diagram showing activity duration.

Source: Heeks and Stanforth, (2014)

Explaining that once the solution to the problem is defined the critical path is then achieved, resulting in having a number of options obtainable from the result set menu (Olawale and Sun, 2015).

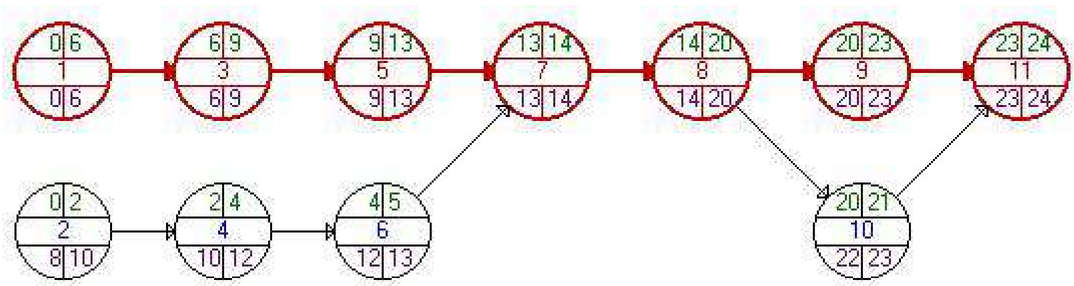


Figure 2.1 : Activity-on-node

Source: Heeks and Stanforth, (2014)

Figure above shows the project network having 11 tasks and a finish/start (FS) precedence relation that exists between the activities. Olawale and Sun (2015) critically studied the relationship between the activities on arrows and concluded that each number at the top of the node indicates the predicted time in the activity will be completed. Further, they stressed that in some scheduling approaches such as PERT/CPM, projects are not subject to any limited resource, and therefore, the development of a baseline plan or schedule still depends on sequencing all tasks based on their precedence relations.

According to Heeks and Stanforth (2014), the network diagram tools such as in figure 4.0 assist the project manager in the construction industry to decide the critical path, which is described as the most extended sequence of activities in the network diagram (which cannot be done in parallel) and which then decide how soon the task can be finished. Nafkha and Wiliński (2016) assessed the slack in the critical path, adding that all tasks on the critical path have to be finished as planned, or else the date of completion of the construction project will start to slip, which can cause the whole project to linger or delay.

Rolfe et al. (2016) criticized this project management tools, suggesting that it is difficult to understand and a waste of time, especially when trying to meet the client's requirement in terms of time of project delivery. Others argued that the tool seems to be complicated, though it is applicable in most organizations in developed countries, especially in an environment where resources are available and in a large construction company that has the financial ability to purchase it, though this may not be cost-effective to smaller construction companies. Also,

Olawale and Sun (2015) observed the thinking of others in developing countries, particularly in Nigerian construction companies, regarding this PM planning tool: their finding revealed that not many construction organizations seem to have a good knowledge of these tools, and the few that use it, employed it basically at the initiation phase of the project, while the majority do not use it because of its complexity and cost. However, Behnam et al. (2016) concluded that lack of trained personnel also contributes to low levels of its application in construction Projects.

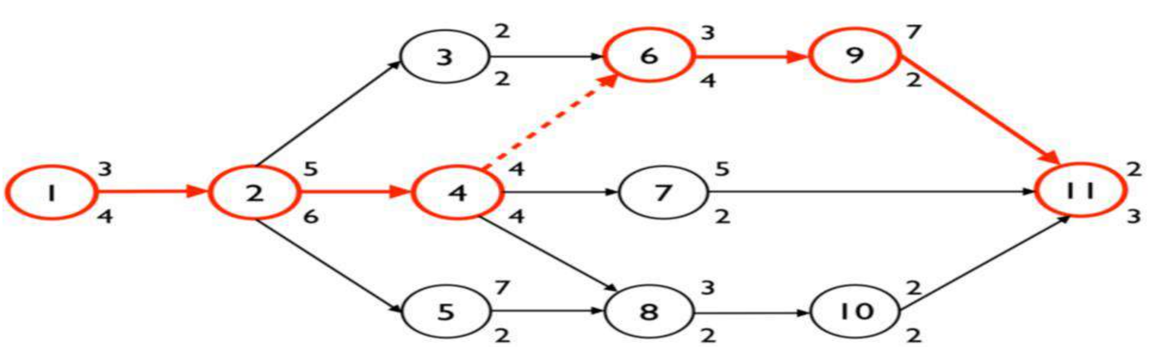


Fig. 2.2 : Activity-on-arrow

(Source: Heeks and Stanforth, 2014**)**

2.2 THEORIES OF THE STUDY

This section evaluates the theories that underpins this study

2.2.1 The Social Cognitive Theory (Bandura, 1986)

Focus of the Social Cognitive Theory (SCT) is on the concept of self-efficacy which is defined as "the judgment of one's ability to use a technology to accomplish a particular job or task" (Compeau and Higgins, 1995).

According to SCT, behaviour of the user is influenced by expectations of outcome related to personal as well as performance-related gains. Self-efficacy, in turn, influences the expectation of outcome of both types. While esteem of the person and his sense of achievement relate to personal outcome expectations, outcome expectations related to performance on the job lead to performance related expectations. According to SCT, there are two opposing factors that influence behaviour of the users. Positive contribution is made by the factor "affect" which is the extent to which an individual likes his job. On the other hand, negative contribution to desired behaviour is made by the factor "anxiety" which is the anxious reaction of the person while performing a job such as trying to use a computer with which the person is not very familiar. This theory has been widely used in adoption studies.

The implication of this theory is that ability of the project managers and other stakeholders to use effective software in the management of their high-rise building projects is dependent on their expected outcome of eliminating construction cost overrun and delays and ability to detect and eliminate risk. This could only be possible if the stakeholder would like to eliminate these unwanted factors.

2.2.2 Technical Adoption Model (Fred, 1989)

The Technology Adoption Model (TAM) is a popular and well-established framework in technology adoption studies, valued for its simplicity and elegance. With its focus on two core constructs – perceived usefulness and perceived ease of use – TAM provides a robust predictive model for understanding individual adoption of new technologies.

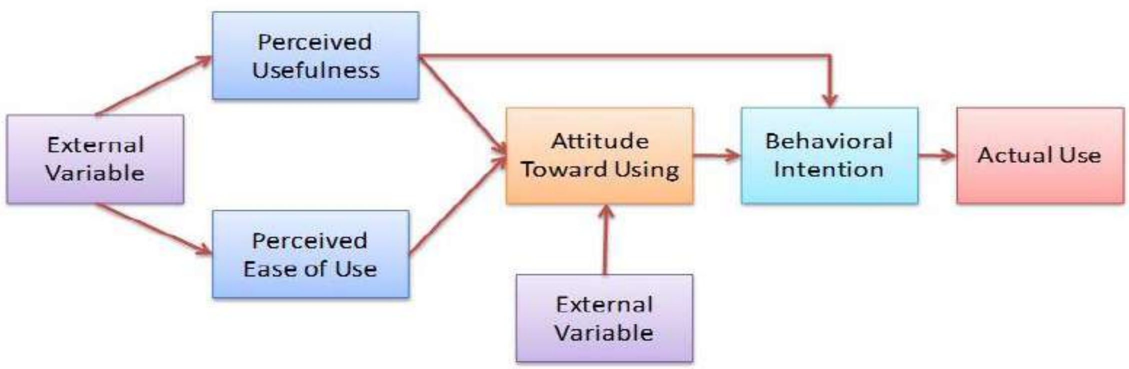


Figure 2.3 (a): Technology Adoption Model (Davis et al, 1989)

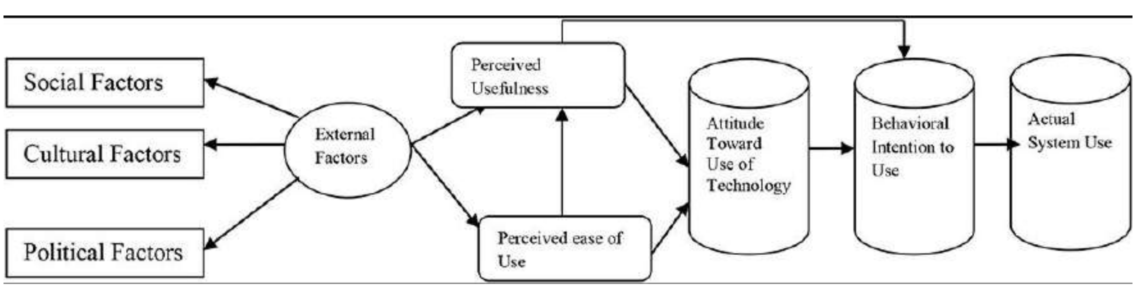
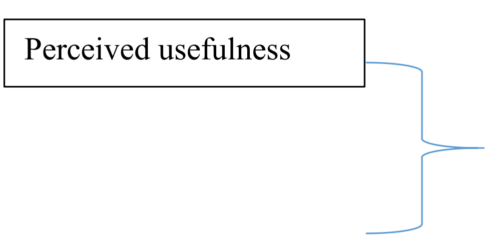


Figure 2.3 (b): Technology Adoption Model (Davis et al, 1989)



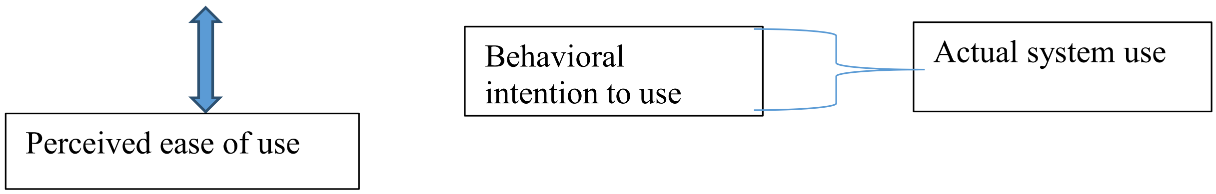


Figure 2.3 (c): Technology Adoption Model (Davis et al, 1989)

These constructs are derived from Bandura's Self Efficacy Theory (1982) which defines perceived ease of use as "the judgments of how well one can execute courses of action required to deal with prospective situation" and from Rogers and Shoemaker (1971) paper which defines complexity (interpreted as ease of use) as "the degree to which an innovation is perceived as relatively difficult to understand and use".

TAM was originally tested in the context of adoption of email service and file editor at IBM Canada with 14 items on each of 2 constructs. The results of the survey on sample of 112 users validated the model with the finding that perceived usefulness is a stronger factor than perceived ease of use that drives technology adoption. In next ten years, TAM became well-established as a robust, powerful, and parsimonious model for predicting user acceptance. King and He (2006) presented a meta-analysis of TAM and found that it is a valid and robust model with applications in a wide range of areas. Dwivedi et al (2010) carried out a comparison of TAM and UTAUT (Venkatesh et al. 2003) and found that focus is now shifting away from TAM to UTAUT while citing in the research articles. In another study, Benbasat & Barki (2007) have criticized TAM especially on the grounds of its limitations in the fast-changing IT environment.

The implication of this theory is that, the easier a project management software is to use, the more it could be applied in project management. Again the less complex the framework of this study is, the more will be the application.

The study adopted both Social Cognitive Theory (SCT) and Technology Adoption Model (TAM) to develop a framework for optimizing project management tools in high-rise building construction in Lagos State, Nigeria.

The SCT is evident in the study's emphasis on the importance of effective management of cost, time, and scope, as well as the identification of major problems and their implications for project delays, cost overruns, and safety risks.

The TAM is reflected in the study's focus on the characteristics of effective project management tools, including cost analysis, communication, estimation, and quality management, which are necessary for addressing prevalent industry challenges.

Therefore, the study adopted a combination of Social Cognitive Theory and Technology Adoption Model to develop a framework for optimizing project management tools in high-rise building construction.

2.3 EMPIRICAL STUDIES

This section shows the review of the related literature as studied by other authors in the industry.

2.3.1 Challenges in High-Rise Building Production

The survey carried out by Spolecnost pro projektove rizeni (in Kratky, et al., 2012) also implies that the main reason for failed project implementation is seen in the problems connected with insufficiently qualified human resources. The other mentioned problems included problems connected with changes in the implemented projects, a wrong definition of the target and scope of the project and problems connected with processes (e.g. failing to follow the procedures, inaccurate project planning or problems in communication).

The Ernst & Young survey (Ernst & Young, 2011) came to similar conclusion according to which the main reason for a project failure in the Czech Republic is a change in the project scope, either for the reason of subsequent changes during implementation, or for the reason of inaccurate project definition in the initial phase. The other reasons for a project failure were seen in different project output expectations and low support from the side of the management.

According to the Information Week´s 2012 Enterprise Project Management survey (Feldman, 2012), the main reasons for a project failure are insufficient human resource capacities, poor requirements planning, problems in communication and insufficient budget.

The Project Management Institute survey (PMI, 2012) came to a similar conclusion according to which it is possible to see the main reasons for a project failure in underestimation of project preparation, insufficient support from the side of executive sponsorship, inaccurately set project benefits and failing to manage changes.

Construction projects are considered complex at all times and since 2nd World War have become increasingly complex. Actually, the construction project can be regarded as the most complex business environment. The industry has shown great difficulty handling the growing complexity of key project in construction industry. Therefore, having a better insight into project complexity is essential to the project team (Baccarini, 1996 city by Gidado & Hannah, 2008).

Mills (2001) explained that construction organizations are the most risky, dynamic and challenging industry with poor reputation for risk management and with several failed projects. Furthermore, the construction projects are instigated in a complex environment resulting (Gidado & Hannah, 2008) in a situation of high risk and uncertainty, which are intensify by arduous time constraints. Studies indicates that interrelationships existing among projects elements are more complex than what is stated in the conventional work breakdown structure (WBS) of project network. Identifying the factors that increase or influence project complexity is vital to the project manager (San Cristóbal et al., 2018).

Luo et al. (2017) determine three different factors that increase project complexity, these include: (1) rapid environmental change, (2) increase in time pressure and (3) and increase in production complexity; while (Gidado 1996, city by San Cristóbal et al., 2018) identify four various sources of complexity; environment, employed resources, technological knowledge and scientific.

Apart from project complexity, study also recognize that the term complexity has also cut across tools and techniques use in project management. Most of the tools adopted in PM are complex and very difficult to use, for example technological tools (software tools) (Matharu, et al., 2015) which is difficult to understand and are not friendly to the end user. Gantt chart tool when loaded with more activities can be very complicated (Mubarak, 2003) to understand, also project scheduling tools (crashing tools) are not rolled out as they demonstrate some element of complexity when it is fully applied either to a single project or multiple projects, thereby reducing the rate of adoption even in the private construction companies in Nigeria (Olateju et al., 2011). As a result of this, adopting complex software tools is challenging and in order to manage this, Olateju et al. (2011) suggest that these tools could be applied gradually in the project.

2.3.2 The performances of Management Tools For High-Rise Building Production

The main part of the survey carried out by Spolecnost pro projektove rizeni (Kratky, et al., 2012) was focused on the cognizance of individual project management tools and their utilization. The cognizance of project management tools is relatively high. The Pre-Project Study with Formalized Structure, the Logical Framework Approach, the Time Planning Using Schedules and Critical Paths, the Project Financial Evaluation and the Formalized Risk Analysis are familiar to 90-98% of the respondents. Even most other project management tools are known to more than 75% of the respondents. The only tool that is not very well-known is the Agile Project Management methods, which have not been encountered by 43% of the respondents. While the awareness of these tools is relatively high, their utilization in practice is lower. The most widely used project management tools are the Time Planning Using Schedules and Critical Paths (67%), the Work Breakdown Structure (66%), the Project Financial Evaluation (62%), the Responsibility Assignment Matrix and the Formalized Risk Analysis (61%). By contrast, the least widely used tools are the Earned Value Management and the Critical Chain Method (17%).

Of the tools indicated by the PMI BoK (1996) as being generally available it was asserted that it was *"earned value analysis (EVA) in its various forms is the most commonly used method of project performance measurement"*. EVA is based on the combined workbreakdown structure (WBS) and the organizational breakdown structure (OBS) for the projectbeing constructed being drawn together so as to develop a task responsibility matrix (TRM). Winch [2002] determines that such an analysis can facilitate what he terms as a cost control cube to be formed and that such an approach provides a disciplined framework for the organizing, planning, budgeting, measurement monitoring, and reporting of a project's performance.

Fleming and Kopplemann [2001] asserted that if EVA was to be implemented efficiently then it was best employed from the earliest stages of the project's development. If this was the case with the use of EVA on construction projects in the UK then it would be necessary for consultant quantity surveyors and other built environment professionals to develop appropriate skills to ensure its application.

However, Baker [2003] identified that many such practitioners see EVA as being a complex process, which is shrouded in terms, acronyms and formulae that can be intimidating to the uninitiated. On the other hand sources such as Webster [2002] asserts that the use of EVA provides a uniform measure for reporting progress on a project and a consistent method of cost performance analysis. The benefits of using EVA as a tool for the measurement of project production cost performance was also given emphasis by its inclusion within the BS6079 and the PMI BoK [1996]. Such sources maintained that the use of EVA would allow a more disciplined approach to planning and risk management, as well as providing good program visibility, and encouragement to the objective and quantitative performance measurement on projects. It was asserted that such an approach would enable timely indications of problems to be developed which would facilitate a more reliable prediction of program cost schedules.

However, the survey run by Spolecnost pro projektove rizeni (Kratky, et al., 2012) implies that 38% of the respondents do not use any software tools for project management. This negative result is affected by the fact that it is the average value. A detailed analysis found out that utilization of specialized software tools increases together with the prolonging practice of project managers, the growing size of budgets and the number of solved projects. As for the type of specialized software, more than 83% of the respondents, who declared use of some software tool, use Microsoft Project.

For comparison, the Information Week´s 2012 Enterprise Project Management survey (Feldman, 2012) found the share of organizations using specialized software for project management of 98.8%.

According to Price water house Cooper survey carried out in 2012, suggested that 77% of participants adopt project management methodologies as well as software. According to Pereira et al. (2013), software tools that conform to both Project Management Body of Knowledge (PMBOK) and Capability Maturity Model Integration (CMMI) can manage PM processes effectively and obtain project success. The scholar also maintained that many PMTT are not aligning with state of the art of project management practice.

Andrew (2013) takes factory building(G+3) situated in cochin, Kerala. In this study author emphasis on the importance and purpose monitoring the construction work, perfect schedule for the factory construction process, layout for updating the calendar, earned cost study& tracking for the standard design factory construction work. The total contract value of project is 7 crones with the build-up area of 5472sq.m and expected time of completion is 21 months. The study includes monitoring and controlling of project by means of primavera software.

Techniques followed by author are:

i. Earned value supervision,

ii. Cost performance baseline,

iii. Work performance supervision.

Muhammad (2016)focusing on how to select appropriate software for project management purpose. In this paper author predicts which of the among software tools are best for the project management purpose.

Author also discuss the web based project management tools in this paper.

For this purpose author uses following software's:

i. Primavera

ii. MS Project

iii. Gantt Project

iv. Redmine

v. Basecamp

vi. Dot project

vii. Assembla.

Author compare each software regarding software's features.

Reddy (2015)says that resource plays important role in any construction project. The performance of any construction project directly depends upon resource management. For the purpose of resource optimization and leveling author choose primavera p6 software in ongoing construction project in Dubai at UAE. The main Objective of the paper was to minimize under allocation of resources. After using primavera software author concluded that there is 5.65% resource reduction.

Unmesh (2015)says that in each year big amount money wastage due to improper resource management. This improper management of resources also causes increase in time duration. Using Primavera software, we can organize our project and recognize potential problems. Primavera software is used for making project management easier, especially when we encounter difficulties Planning the project means thinking about, and documentation.

Ankit & Sanjay (2020)have studied leveling resources for construction project G + 3 hospital by various software-based leveling tools. The objective of this paper was to calculate an optimum schedule for construction project resources. The studied work represents a comparison of resource leveling by leveling tool of primavera and MS project. In this paper, the author applies different type of leveling tool to examine the best leveling tool. Leveling tool available in both software. Activities can split to be leveled in MS-project unlike in Primavera.

Suvarna, Yateen, & Mahendra (2018)have studied planning, scheduling, and tracking of bridge construction by using primavera software & the EVM technique. The location of the project is Sangapura. Construction started in January 2016. The duration of the project as per the baseline schedule is 867 days. Conclusion of literature proved to help measure constraints performance of a project in EVM and enable the analysis of the efficiency of various parameters related to the progress of the report. Following steps of the methodology followed by authors:

- Implementation of primavera p6 on a project.

- Calculation of critical path of the planned schedule.
- Calculation of earn value management.

Anurag and Amit (2018)have studied project management of 200 trainee hostel building by using primavera software. The project is located at the campus of Dr. Panjabrao, Deshmukh prabodhini Amravati. The contract period of project construction was 24 months. Conclusion of work observes an implementation of planning and scheduling by using primavera software the time duration was reduced by nearly 3 months.

Mohammad, Siddiqui, Abhijit & Bhirud (2018)have studied, project management in Pune metroMaharashtra. The author tried to demonstrate the planningfor a stretch of 10 K. M. of the metro bridge from PimpriChinch wad to Range hills. The conclusion of this paperwork was the estimation in a period of the Pune metro project by using primavera software. The estimated duration of the Pune metro duration by the author was not considering a major cause of delay. The future scope of studies is updating and monitoring the schedule work.

Vishal and Balasaheb (2017)have studied planning, scheduling & allocation ofresource of a multi-storied building by using primaverasoftware. The location of the project is Pune Maharashtra.Literature explained the importance of oracle software primavera in the construction field and applies it to the management of a multi-story structure. He finds out the estimated finishing period for the project and plans it along with resource allocation and helps us to understand the concept of primavera in a precise manner giving an example of works done in Primavera P6. He concludes that the main objective of his study was to know the role of planning and management of the project within the duration accomplishment of any construction project. His project was fulfilled with the help of literature references and unique methodologies in control and monitoring using project management application.

Esaki (2016) has used primavera software for planning of road construction. Time supervision system is focused to complete a key role in a construction company, which is accountable to finish the project in budget value within a certain duration. Poor task management and fund performance are major problems faced by construction organizations. The objective of this research is to prepare the planning and management for road work construction at VOC PORT TRUST, Tuticorin. Primavera P6 software helped for monitoring and controlling the road project work.

Reddy (2015)says that resource plays important role in any construction project. The performance of any construction project directly depends upon resource management. For resource optimization and leveling author choose primavera p6 software in an ongoing construction project in Dubai in UAE. The main objective of this paper is to minimize under allocation of resources. After using primavera software author concluded that there is a 5. 65% resource reduction.

Subramani, Sarkunam, & Jayalakshmi(2014) have studied comparison in time performing of the conventional method of construction for residential and industrial building system method by total construction duration. Schedule work was developed using oracle software primavera. The positive change includes creating a healthy working environment among those involved directly in the construction industry. The major players in the engineer’s town planners, contractor and supplier or manufacture have to play their duty in enhancing their working system, management, and administration to enable the modernization in the company.

Andrew & Sachin (2013)have work explained project planning and controlling is the process of collecting information concerning project performance. The study deals with the monitoring process of a four-storied (G+3) factory building in Cochin Kerala. A comparison between the planned progress of construction work and actual progress is performed in this study using primavera software. The methodology followed by the authors are

-Earn value supervision

-Cost performance supervision

-Work performance supervision

2.3.3 Deficiencies of the Project Management Tools Used for High-Rise Buildings Production

Cheng (2005) looked at some of the limitations associated with some of these PMTT, arguing that "Bar chart" lacks logical representation and do not show the relationship that exist between the entities, adding that though most software tools have depicted logical (Cheng, 2005) relationship on these tools, the outcome have always been negative. Secondly, Gantt chart on the other hand only demonstrates one possible event, which is, a single situation. When undertaking any type of project, there are a lot of changes that occurs. For instance, within a private construction project, the project manager may experience an absence of detailed information concerning the final foundation type as well as design since Gantt chart may not represent the entire information required in the project due to limitation in the bar (Ballesteros-Pérez, 2018). Gantt chart can become difficult and challenging, except for those projects that are very simple without much activities and complexity. When loading its bar with a large number of activities it becomes very complex, however, this complexity can be managed by some software tools such as Mavenlink, Wrike, Smartshet and AceProject (Mubarak, 2003).

Pajares and López- Paredes (2011) evaluated Earned Value Management (EVM) used for controlling and monitoring projects, and claim that the major limitation of EVM is that it does not consider project uncertainty as well as variability, as it uses deterministic. Also, when it is integrated "schedule control index and cost control index" to manage project uncertainty, result shows that it become too complex for most practitioners in construction industry (Pajares and López- Paredes, 2011).

Hall (2012) asserts that, for project controlling and schedule monitoring,decisions making most of the time are very difficult because of project complexity. For example, "crashing decisions become much more complex especially when task times areuncertain," (Pajares and López-Paredes, 2011).

Other limitation of these tools is that it is costly especially the software tools. For most organizations the price tag is the key reason why these companies are not embarking on these software tools, besides the cost implication, the maintenance cost and implementation particularly when the project manager and project are not familiar with the current technology is another limitation associated with these tools (Andra, 2018).

Even though hundreds of studies are being conducted on project schedule management and BIM, only 30%-40% of companies are enjoying its benefits (Amir et al., 2019). The perception toward BIM, availability of practical applications, costs of implementation, and longer learning curves are major drawbacks deterring companies from implementing it. Studies pertaining to complex algorithms, such as machine learning, AI, etc., require large databases related to construction activities. This would be practical only if integrated with a sensor network and a real-time data monitoring platform, which is complex, expensive, and varies with local decision-making approaches.

According to the literature, several challenges continue to deter the implementation of BIM, such as the inability to utilize the software tools to their maximum capacity, cost of implementation, as well as a hindrance in data sharing.

2.3.4 Technologies or Project Management Tools that can Help Eliminate Challenges in High-Rise Buildings Production

As a repository of project life cycle data, BIM can be an effective tool in executing predictive decision-making (Lam et al., 2017). In the following sections, various methods used for BIM-based decision-making in construction management are discussed.

2.3.4.1 BIM- based schedule management

BIM-based schedule management is gaining significant traction today (Aredah et al., 2019; & Wang, 2019). The Fourth Dimension (4D) of Building Information Modeling is a characteristic of BIM-based schedule management technology that is built on the information embedded in the model. Schedule management can model and analyze sequencing activities within a constructionschedule with respect to time and space. In the domain of BIM-based schedule management, previous researchers have focused on the following three areas:

i) minimizing schedule overlap and delay, ii) automated scheduling, and

iii) detection of errors and missing data.

Overlaps in activities and potential delays in a construction site lead to changes in the project timeline and schedule. If specific project activities are delayed, it can risk deferring the completion date of the entire project (Dehghan & Ruwanpura, 2011). Overlapping tasks may emerge in both highly intricate project schedules as well as high-level summary schedules.

Moon et al. developed an active construction schedule management system by integrating BIM with fuzzy-based risk analysis algorithms and genetic algorithms (Moon et al., 2015). This method was used to create an optimal schedule with minimum overlaps. Managementof a construction project in the design and execution phase heavily depends on easy access to data (Chassiakos & Sakellaropoulos).

The integration of BIM and GIS is of great significance in the geospatial section because of the rising research interest in smart cities, Internet-of-Things, and urbanization (Deng et al., 2019a, 2019b). Bansal and Pal's early attempts at 4D visualization of construction sequence were carried out by linking GIS and project schedule with a 3D model of the project (Dehghan & Ruwanpura, 2011; Wang & Song, 2016). This process informed and educated less experienced project participants about what must be built and its scheduled time and location of installation.

Irizarry and Karan integrated BIM and GIS to determine the optimal locations of tower cranes. Through this research, they solved the problem of identifying optimal locations for a minimal number of tower cranes to eliminate potential conflicts in the schedule (Irizarry & Karan, 2012).

Furthermore, Chen and Tang proposed a workflow design integrating BIM and digital programming to address schedule and cost uncertainties during the maintenance stage, which can prevent delays in building maintenance (Chen & Tang, 2019).

Chen and Nguyen integrated BIM and Web Map Services (WMS) to simplify and optimize construction material selection (Chen & Nguyen, 2019). This approach provided substantial data related to material, such as sources or vendors, storage locations, availability, costs, and transportation methods that help the project team estimate the final cost and delivery time of the material to guarantee optimal inventory and timely delivery of materials. Integration of semantic web with BIM and GIS can assist the construction manager in improving access to data, eliminating paperwork, recording data in a multimedia format, removing inaccuracies in the documents, and improving collaboration among the project participants (Chassiakos & Sakellaropoulos, 2008). This approach reduces delays and extensive costs associated with traditional document management.

Automated scheduling has been a key domain in BIM based schedule management research. The estimation of an activity duration is a challenge in the pre-construction stage. Accurate activity duration directly correlates with projecting management experience.

A study conducted by Hexu et al. recommended an automated scheduling approach using an add-on to Autodesk Revit (Liu et al., 2015). The algorithm can define the optimal activity duration considering the attributes of the project and user-defined constraints on different activities.

Getuli and Capone developed an ontology-based automatic scheduling system in the BIM platform that utilized construction scheduling knowledge as a foundation (Getuli & Capone, 2019). Knowledge-based scheduling ontology enhanced the semantic representation and efficiency of supporting processes in construction schedules (Getuli, 2020).

Moreover, Wang and Rezazadeh proposed a BIM-based framework to create project schedules of concrete-framed buildings. This method leverages prior knowledge to devise rules after considering building objects and their attributes and then generates a list of work packages, their duration, and sequences (Ziwei Wang, 2019).

Li et al. applied BIM and Radio Frequency Identification Device (RFID) to enhance coordination between project stakeholders. This method analyzed the critical schedule risk factors and developed an automated RFID-enabled BIM platform that integrates various stakeholders and information flow to manage risk factors. This research attempted to ensure timely project completion in prefabricated housing construction by addressing schedule risks (Li et al., 2017).

Cheng and Chang presented an optimization model for BIM-based site material layout planning (Cheng & Chang, 2019). This method addressed delays in logistics and enhanced the efficiency of construction.

2.3.4.2 BIM- based cost management

Cost optimization leads to more profits with acceptable quality, safety, and schedule in AEC projects. Further, cost optimization ensures that the cost of construction does not exceed the budget and maximizes the profit in the design stages (Rajguru, 2016). Traditional cost accounting methods are often inaccurate and inefficient since the design undergoes frequent changes in the early phases.

A fully integrated BIM environment combined with cost estimation software, also known as the Level 03 BIM platform for embedding cost dimension (5D BIM), is an ideal solution for cost management in AEC projects (Eastman et al., 2011). Previous BIM-based cost management research entails three key research areas: i) automated cost estimation and prediction, ii) cost optimization, and iii) Financial risk management. Automated cost estimation has been the most popular area of research in BIM-based cost estimations.

Zhiliang et al. proposed an Industry Foundation Class (IFC)-based model for estimating construction costs. The extended IFC standards presented in this study provide division-item property sets, cost items, and mathematical relationships (Zhiliang et al., 2011).

Lee et al. proposed an automated work item searching system developed through the integration of BIM with an ontological inference process. The proposed approach assists cost estimators in employing BIM data to find work items and their quantities. Moreover, it eliminates the need for the intervention of the cost estimator's subjectivity (Lee et al., 2014).

Xu et al. proposed a framework by integrating BIM with semantic web ontology and forward chain algorithm to establish new means of obtaining and deriving data from a BIM model. Such data was used for developing the essential items to perform the quantity takeoff. The proposed framework helps the AEC industry with the development of an automated cost estimation system (Xu et al., 2016).

Cheung et al. proposed a BIM-based cost estimation module to assess different aspects of building design in the early design stages. The multi-level cost estimation tool presented in this study enables users to automatically obtain measurements from 30 models and evaluate the functionality, economics, and performance of buildings (Cheung et al., 2012).

Lawrence et al. integrated BIM with query language to propose a generic approach for creating and updating a cost estimate. The outcome of this approach adds flexibility to cost estimation and enables the estimator to encode a wide variety of relationships between the design and the estimate (Lawrence et al., 2014).

Niknam and Karshenas integrated BIM and semantic web service technologies, as well as ontology inference processes to improve the accuracy of cost estimation (Niknam & Karshenas, 2015).

Wang et al. proposed a method that utilizes BIM and cost-based progress curves to identify construction progress curves (Wang et al., 2016). This method identifies take-off objects to obtain quantities of cost items related to each activity. This study shows that this method can prevent errors that emerge when manually typing cost-item names (Wang et al., 2016).

A study conducted by Pathirage et al. entailed the development of a BIM-based method to highlight change orders and minimize project costs (Pathirage & Underwood, 2015).

Faghihi et al. proposed a cost optimization method based on the integration of BIM with Pareto Front analysis. This study presented a tool to help project managers to optimize project cost and scheduling (Faghihi et al., 2016).

Eleftheriadis et al. integrated BIM with Genetic Algorithm (GA) and Finite Element Modeling (FEM) to develop a cost optimization approach and embodied carbon of reinforced concrete structures. This approach enables managers to make early design decisions considering the costs and environmental implications (Eleftheriadis et al., 2018).

He et al. developed a five-dimensional construction cost optimization model by integrating BIM with GA. The proposed system provides solutions for managers to prevent cost and time overruns in construction projects (He et al., 2019).

According to a study conducted by Huang, unforeseen costs can be reduced from

50 to 15% using BIM. Risk factors due to uncertainty and the inability to visualize the project are mainly addressed through the proposed approach (Huang, 2021).

The literature reveals that Cha and Lee proposed a BIM-based framework to identify work items in construction sites and the relationships among activities to reduce human error and increase work efficiency (Cha & Lee, 2015).

Sun et al. proposed a project cost and schedule risk early warning model by integrating BIM with Earned Value Analysis (EVA). This study also addresses the problems and challenges of traditional EVA methods that rely on the experience of project participants in construction management (Sun et al., 2015).

Shan et al. developed a BIM-based approach for cost management across the processes in high-risk construction projects. This research proposes the reduction of pipeline clashes, reworks, and project costs as potential solutions to minimize the risk of high-risk AEC projects (Shan et al., 2018).

Reviewing BIM-based cost management literature revealed that automated cost estimation has begun to garner more attention in the recent past. Automated cost estimation increases the speed and accuracy of cost prediction (Mittas et al., 2015). BIM-based cost management offers many advantages, such as advanced and automated quantity take-off for cost estimation in highly dynamic environments, estimation based on big data, optimum output choices from different scenarios, and web-based collaboration.

2.3.4.3 BIM- based safety management

Previous research on BIM-supported safety management has focused on (i) enhancing on-site communication, (ii) construction hazard detection, and (iii) safety planning in AEC projects (Zhang & Hu, 2011). BIM supports communication and collaboration, enabling the project teams to share their knowledge and propose safety improvements throughout the project life cycle.

Dossick et al. investigated the role of BIM in augmenting coordination and collaboration in a construction project (Dossick et al., 2010). This study concluded that BIM is necessary to navigate a complex project hierarchy with a large volume of data and facilitate information exchange between project participants.

Ganah and John suggested adopting BIM in toolbox talks (Ganah & John, 2015). The BIM-based visual aid will enhance the effectiveness of safety hazard identification and the team's communication and collaboration.

Teo et al. developed a BIM-based intelligent productivity and safety system to aid project stakeholders with the collaborative assessment of the safety performance prior to the project commencement (Teo et al., 2017).

Golparvar-Fard et al. proposed the integration of BIM and 4-Dimensional Augment Reality (AR) to present a better visualization of construction operations and their sequences. The authors revealed that this model could provide easy-to-understand and detailed attributes for remote project monitoring (Golparvar-fard et al., 2011).

Le and Hsing integrated BIM with a mobile web map service and GIS coordinates to support data exchange in real-time and manage any risks to adjacent buildings and the neighborhood (Le & Hsiung, 2014).

Nawari integrated BIM with the Information Delivery Manual (IDM) to resolve problems associated with augmenting the national BIM standard to facilitate more reliable data exchange between project participants, which enhances information quality and ensures prompt communication (Nawari, 2012).

Niu et al. presented a BIM-based framework for augmenting construction resources with technologies concerning autonomy, awareness, and the ability to interact with their vicinity to function as smart construction objects. The proposed method enables a safer, greener, more efficient, and more effective construction system (Niu et al., 2016).

Park and Kim integrated BIM with AR, location tracking, and a game engine to improve the real-time collaboration between managers and workers. This method helps project safety managers monitor their workers in a safe manner during the construction phase of projects (Park & Kim, 2013).

Getuli et al. implemented a BIM and VR-based safety training protocol and safety oriented planning approach for the construction industry, further enhancing BIM utilization in the safety management process (Getuli et al., 2020a, 2020b).

Chen et al. improved and augmented fire safety and safety up skilling through the integration of BIM, the Internet-of-Things, and AR/VR technologies (Chen et al., 2021).

Ciribini et al. developed a 4D BIM-based interoperable procedure to conduct safety based code checking and analyze the construction phase. This proposed process enables managers to ensure construction worker safety (Ciribini et al., 2016).

Malekitabar et al. detected more than 40% of potential fatalities in construction projects through five sets of safety risk drivers as construction incident sub-causes to help managers. These safety risk sub-causes can be derived from a BIM model (Malekitabar et al., 2016). BIM has been an effective method for safety management in confined workspaces.

Chavada et al. used BIM in conjunction with the Critical Path Method (CPM) to accurately manage workspaces on construction sites and prevent workplace incidents (Chavada et al., 2012). In the above study, the integrated system enables safety managers to monitor construction workers and prevent safety incidents using BIM-supported decision-making platforms (Jeewoong Park et al., 2017) and allows construction managers to undertake preventive measures during the pre-construction stage (Qi et al., 2014a).

Qi et al. and Zhang et al. proposed BIM-based methods to check fall hazards (Qi et al., 2014b). Within this context, BIM was integrated with other technologies, such as real-time locating systems, wireless sensing, and real-time audio warning for safety-focused applications.

Wang et al. used BIM with range point cloud data to detect fall hazards in geotechnical projects (Wang et al., 2015a, 2015b). Protective measures for falls were proposed upon identifying the fall hazards.

Akula et al. presented a method based on the integration of BIM with 3D imaging technologies to identify safety hazards when placing embeds into existing reinforced concrete structures (Akula et al., 2013).

Ding et al. used BIM and semantic web technology to model construction risk and develop risk responses. This framework produced a risk map and recommended a risk prevention plan (Ding et al., 2016).

Golovina et al. investigated hazard causes related to construction equipment and proposed a GPS and BIM-based method for recording, detecting, and analyzing interactive, hazardous near-miss situations between workers on foot and heavy construction equipment (Golovina et al., 2016).

Hu et al. presented a BIM-based framework to detect construction collisions for site entities (Hu et al., 2010a). This algorithm used boundary representation (B-rep) to detect collisions (Hu et al., 2010a).

Hu et al. developed a 4D BIM model that provides comprehensive information on dynamic connections between scaffolding systems and the construction process (Hu et al., 2010b). This model was used to analyze the safety of scaffolding and worker behaviors (Hu et al., 2010b).

Mihic et al. linked BIM with a construction hazards database for early hazard detection (Mihić et al., 2018).

Bannier et al. proposed a BIM-based approach to address the safety challenges associated with limited work-space for piping and steel trades crews (Bannier & Goodrum, 2016).

Kim et al. prepared a query set for a BIM model that automatically identifies similar accidents using a project management information system (Kim et al., 2015).

Kim et al. (2016a, 2016b) pioneered the integration of Building Information Modeling (BIM) with automated data collection and real-time locating systems, significantly reducing workers' exposure to hazardous conditions. Moreover, Proactive Behavior-Based Safety (PBBS) represents a novel approach that combines traditional behavior-based safety management with the Proactive Construction Management System (PCMS). This method enables managers to identify potential causes of unsafe behaviors at the execution stages before an accident occurs by automatically monitoring location-based worker behaviors (Li et al., 2015).

Li et al. extended the above study to include PBBS for a BIM model to automatically monitor location-based behaviors, identify the primary causes of unsafe behaviors, and enhance the safety of the construction project (Li et al., 2015).

Luo et al. developed a BIM-based method to check the code compliance of the high-risk deep foundation construction projects (Luo & Gong, 2015).

Riaz et al. linked BIM and wireless sensors to monitor workers working in confined spaces. The proposed system reduces the safety risk for workers in confined spaces (Riaz et al., 2014).

Zhang et al. integrated BIM and GPS to identify and visualize potentially congested workspaces to prevent suffocation hazards for workers (Zhang et al., 2015c).

In addition to the aforementioned studies, many researchers attempted to integrate BIM and Unmanned Aerial Vehicle (UAV) to track worker behaviors in mega construction sites.

Teizer et al. used BIM with UAVs and laser scanning technology to automatically track construction workers and identify and prevent potential hazards (Teizer, 2015).

Liu et al. employed BIM and UAV technology to enhance the level of safety inspection during the construction phase to enhance site safety (Liu et al., 2019).

Cheung et al. developed a system to monitor the safety status via a spatial-colored interface and automatically remove any hazardous gas from the construction site based on the integration of BIM with a wireless sensor network (Cheung et al., 2018). This system uses wireless sensor nodes placed on underground construction sites to collect hazardous gas levels.

Moon et al, 2014a). integrated BIM with a genetic algorithm to develop an active simulation for minimizing the simultaneous interference level of the schedule-workspace (Moon et al., 2014b). This approach aids managers in solving schedule-work-space interference and preventing safety hazards.

Zhang and Hu proposed a BIM-based framework to analyze conflicts and structural safety problems during the planning stage of the project. They argued that this machine is capable of preventing safety issues and accidents from occurring during the construction phase of the project (Zhang & Hu, 2011).

Similarly, Bansal et al. utilized information from the GIS-based activity database in a 4D BIM model to detect safety-based logical errors in the construction phase (Bansal & Pal, 2014).

Zheng et al. proposed an ontology-based semantic BIM modeling to promote holistic inquiry of safety knowledge. With its automated safety planning for the analysis of construction site hazards, this system can efficiently prevent workplace safety incidents (Zhang et al., 2015a).

Choi et al. proposed a BIM-based framework to handle space planning in pre-construction management. This research proposed a decision support tool to resolve safety issues related to workers in construction sites (Choi et al., 2014a).

Mirhadi et al. developed a tool that enables designers to optimize the building layout that supports occupant safety during evacuation (Mirahadi et al., 2019).

2.3.4.4 BIM- based quality management

BIM-based quality management primarily focuses on three research domains: (i) Lean construction, (ii) Collaboration and communication improvement, and (iii) Automated progress monitoring. BIM is effective in implementing modern management techniques, such as lean construction to reduce defects, clashes, and wastage of time during construction projects (Chassiakos & Sakellaropoulos, 2008; Forcada et al., 2007).

Sheikhkhoshkar et al. proposed automated and cost-effective planning to resolve the problem of the conventional construction joint design process (Sheikhkhoshkar et al., 2019).

Porwal et al. proposed a BIM-based method for estimating construction waste from change orders. This method can help reduce construction waste by 25% (Porwal et al., 2020).

BIM-based defect identification and management have been frequently researched in the past. Technologies, such as digital twins, AR, and image-matching, have been integrated with BIM to support clash detection and defect identification.
Park et al. proposed a framework based on the integration of BIM with AR and an ontology- based data collection template to decrease defects occurring during the construction process (Park et al., 2013).

Kwon et al. presented a method that integrated BIM with image-matching and AR to identify omissions and errors at real job sites to enhance defect management (Kwon et al., 2014).

Hamledari et al. developed a technique to automatically transfer site data (based on site observation for inspected building elements) to the BIM model. This system identifies discrepancies between the as-built and as-designed object conditions; therefore, it can assist with defect management (Hamledari et al., 2018).

Elbeltagi and Dawood employed the integration of BIM with GIS to develop a method that can evaluate and visualize construction performance against time. The proposed method reduces potential defects of repetitive actions during the decision making process (Elbeltagi & Dawood, 2011).

Biagini et al. used laser scanning and BIM for construction management in historical building restoration projects by reconstructing a digital twin of the building (Biagini et al., 2016).
The proposed method supports the preservation of historical buildings. Facilitating seamless collaboration and communication among project participants enhances the project synergies while advancing the quality management process.

Kubicki et al. integrated BIM with Smart White Board systems to create synchronous interactive devices to enhance coordination between project participants. It promotes better engagement of team members to make project decisions after considering multi-stakeholder concerns (Kubicki et al., 2019).

Chen and Lu developed a BIM-based method for improving information quantity, quality, and accessibility (Chen & Lu, 2019). The results demonstrated improved data exchange between project participants.

Lin and Yang developed a BIM based collaboration management method to reduce the time required to complete the model checking process. The case study results indicate the potential held by the proposed approaches in collaborative BIM model creation for general contractors (Lin & Yang, 2018).

Ma et al. used BIM with indoor positioning technology to resolve the omission of check items and initiate the process of digitizing inspection results. The outcomes of this study demonstrated the improvement of collaboration among the construction stakeholders (Ma et al., 2018).

Oh et al. presented a BIM-based integrated system to aid collaborative design, which addresses the challenges associated with employing various BIM-based software when collaborating during the design phase and resolving pertinent issues, such as loss of data and difficulty in communication (Oh et al., 2015).

Koseoglu et al. proposed a framework based on the integration of BIM with lean construction principles (Koseoglu et al., 2018).

Larsen developed a BIM-based framework to address the challenges associated with traditional progress reporting. This framework consists of three steps for minimizing manual reporting and improving communication during the reporting process (Mejlander-larsen, 2018).

The third approach to quality management studies is related to progress monitoring. The success of progress monitoring in a construction project depends on detailed and efficient tracking, analysis, and visualization of the actual status of buildings under construction (Golparvarfard et al., 2015). To accomplish this, BIM has been integrated with techniques, such as GIS, UAV, RFID, AR, and laser scanning.

Bosche et al. used BIM with laser scanning to present automated object recognition, which indicated its potential in controlling as-built dimension calculation (Bosche et al., 2009).

Bosché et al. integrated BIM with laser scanning for structural work monitoring. The proposed system provides accurate information from the construction site to improve the progress monitoring process (Bosché et al., 2014).

Dimitrov and Golparvar proposed a vision-based material recognition method based on the integration of BIM with point cloud data. This method can generate a BIM model from unordered site image collections, which can significantly improve the automated monitoring of construction progress (Dimitrov& Golparvar-fard, 2014).

Han et al. developed an appearance- based recognition method using BIM with 3D point cloud models to determine construction progress (Han & Golparvar-fard, 2015).

Braun et al. proposed automated progress monitoring with photogrammetric and BIM (Braun et al., 2015). The real-time point cloud of a construction project is generated through a large number of images captured by a camera. The study proposes an iterative step for construction planning from real-time progress. However, the inability to capture clear images of the whole building, the requirement of large volumes of data to build a point cloud and implementation costs remain the disadvantages of this study.

Costin et al. integrated BIM with RFID to enable real-time tracking and monitoring of construction workers. This integrated method, as demonstrated by the results, can maintain building protocol control (Costin et al., 2015).

Choi et al. used BIM to perform path analysis to enhance monitoring workspaces (Choi et al., 2014b). The proposed framework enhanced the work-space planning process.

Shahi et al. used BIM with imaging and Ultra-Wide Band to track the progress of construction activities (Shahi et al., 2015)

Braun and Borrman developed a method based on the integration of BIM with inverse photogrammetry technique to automatically label construction images. This system enhances image-based object detection, which is the basis of construction progress monitoring (Braun & Borrmann, 2019).

Asadi et al. proposed a BIM-based method to facilitate as-built and as-planned data comparison. This system automatically registers real-time images to a BIM model. Therefore, it aids managers with monitoring construction work indoors (Asadi et al., 2021).

Tezel et al. studied BIM and lean construction and revealed that significantly lesser research attention had been directed toward Small and Medium Enterprises (SMEs), whose contribution to the industry is substantially greater (Tezel et al., 2020).

2.3.5 The Four Project Management Variables:

Effective project management is becoming a critical mission skill for individuals and organizations in every industry. Faster product life cycles, the widespread adoption of cross-functional teams, and the increasing demands of customers are all contributing to the growing need for professional managers who know how to marshal resources, make decisions, and ensure the smooth flow of projects from idea to launch (Robert & James, 2001).

It is outside the scope of this study to discuss how to select project managers, but, for the interested readers, the topic is covered in a book by Wysocki and Lewis titled The World-Class Project Manager (Perseus, 2001).

The **project management triangle** consists of three variables: **Scope**: Refers to the tasks required to achieve project goals, **Cost**: Represents the project budget and **Time**: Relates to the project schedule. See figure 2.3 below.

One of the common causes of project failure is that the project sponsor demands that the project manager must finish the job by a certain time (T), within Cost (C), and at a given magnitude or scope (S) while achieving specific performance (P) level (Josheph, 2011). In other words, **the sponsor dictates all the four of the project constraints.** This doesn't work.

The relationship among the PCTS constraints, written as: C= f(P,T,S). In words, this says "Cost is a function of performance, Time and Scope.

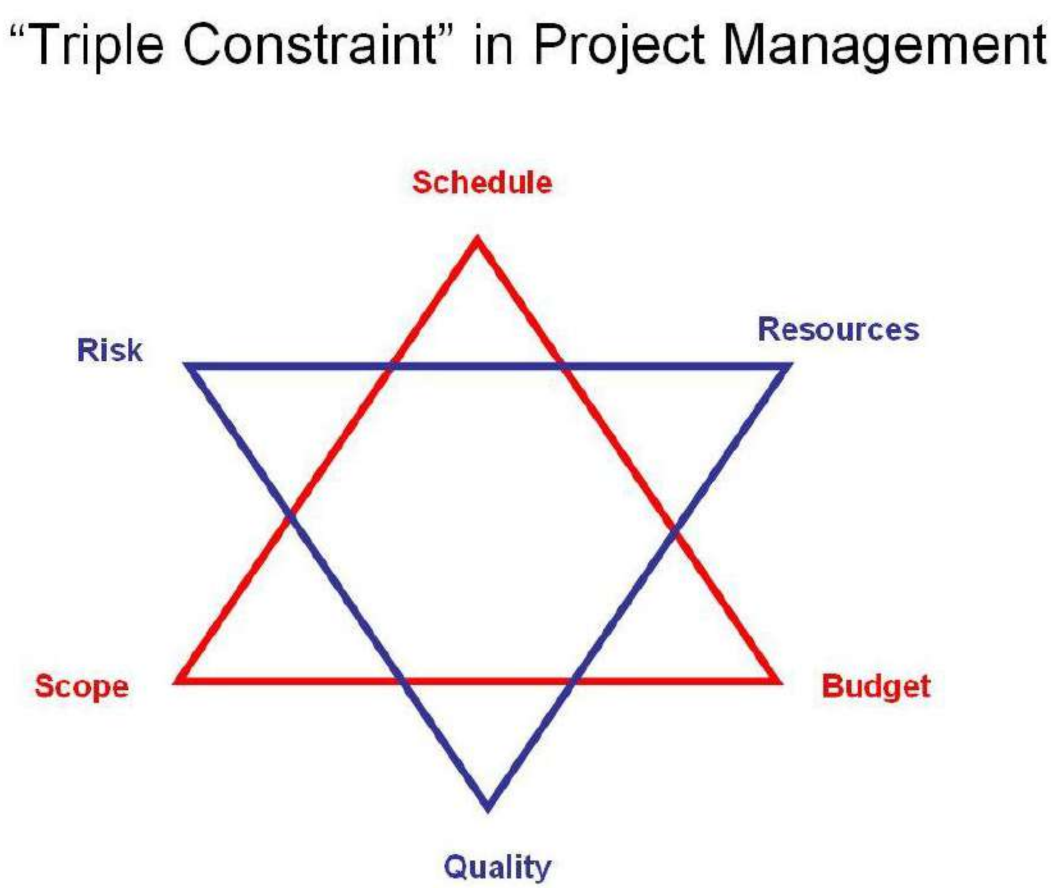


Figure 2.3: Conceptual Framework of the Study

(Source: https://en.wikipedia.org/wiki/Project_management_triangle**)**

2.3.6 Characteristics of a good Project Management Tools

According to Muhammad (2015), a good project management tool should possess the following characteristics.

Task scheduling: task scheduling is the activity of defining the start and end times for activity. The result of task scheduling is feasible project schedule. Most project management tools have features to support task scheduling. The project schedule helps project managers to monitor project milestones, and activities, further, project schedule often changes in projects. therefore, it is helpful when PMSTs provide ease of modifications in the project schedule.

Resource Management: with this feature, project managers allocate proper resources to activities and tasks to meet project requirements. Such resources may include financial resources, inventory, human skills, production resources, etc.

Collaboration: collaboration awareness is important for managing inter-team development activities. These activities often lead to share artifact that requires careful handling. Successful collaboration provides the opportunity to detect potential integration problems in times. Again, it helps to take proactive steps to avoid conflicts and enables sharing of knowledge and best practices. Collaboration can be implemented by integrated e-mail, web pages or wiki pages.

Time Tracking: time tracking enables recording, analyzing, estimating, and reporting the time spent on project activities. With the help of time tracking employers' time-sheets and expenses is managed. A significant cost item, personnel salaries, are calculated. In addition, time tracking leads to a detailed breakdown of project tasks.

Estimating: it is the activity leading to estimate on project effort, cost and schedule. Project managers can generate, manage and validate estimate of effort on projects.

Risk Assessment: a successful risk analysis reduces long term expenses and prevents project failures. Risk assessment enables the project manager to recognize and schedule risk countermeasures during project execution.

Change Management: it is the controlling of project plans, resources, products and cost of project development process. By changing management, the effects of changes on requirements and above issues can easily observed and managed.

Project Analysis/Reporting: it is an analysis of product, person or organization related project development effectiveness by Gantt, PERT, CERT, or other custom formats.

Document Management: it enables managers or necessary project members to customize, share, distribute, recover, authenticate, secure and also manage versions of the document.

Communication Tools: they are used for informing stakeholders and project members about the status of the project and published documents. Communication tools may use e-mail notifications and other means. These tools constitutes foundation for collaborative activities.

Process Development Method: with this feature standardized scheduling of task can be implemented. Project manager can manage various tasks or activities during product development process using these methods.

Portfolio Management: project portfolio management (PPM) methods are used for choosing the right projects for producing the deliverable beneficial to the organization. It enables managing multiple related projects and hence, resource allocation among them.

Access Control: it is controlling access to the resources of the software tool to authorize users and restricting access to unauthorized users.

Quality Management: managing all the activities , tasks, documents etc. related to ensuring a certain level of quality, such as quality level description,, quality planning, quality assurance, quality control and quality improvement.

Web Based: some tools are accessible via a network such as the internet or a LAN

Issue Tracking: creating, maintaining and managing lists of issues related to the project.

2.4 CONCEPTUAL FRAMEWORK

This section presents the variables studied in this work. This study examined three distinct categories of variables, which are: Independent Variables, Control Variables, Dependent Variables. These variables are defined as follows:

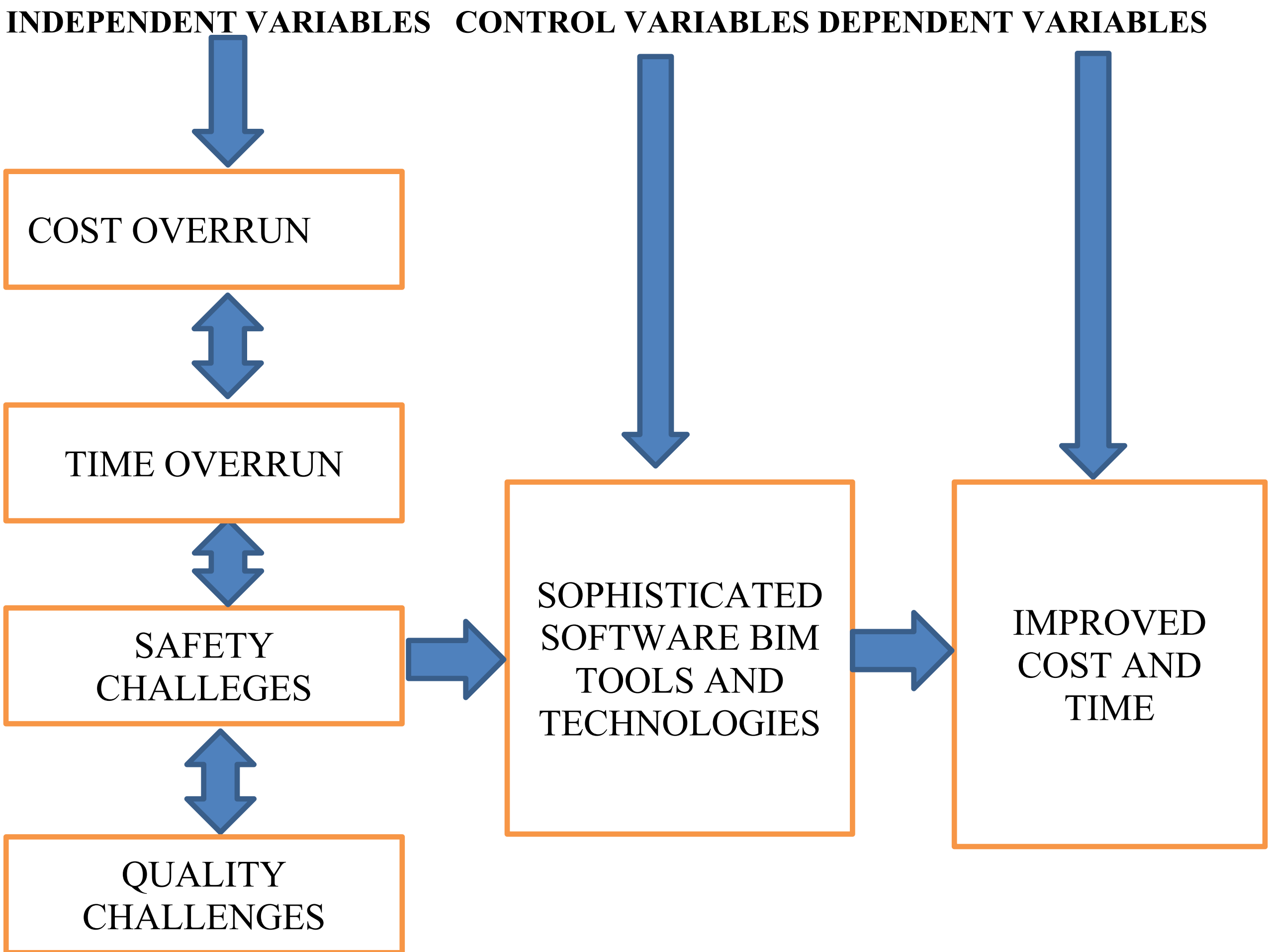


Figure 2.4: Conceptual Framework of the Study

(Source: Researcher's construct**)**

In the framework contained in Figure 2.4, the independent variables are those factors, challenges and deficiencies which are problems related to the HRB production in Lagos state which includes cost overrun, time overrun, safety challenges, quality challenges and the inefficiency of project management tools.

In order to address these challenges, there should be control variables, these variables (either controlled or kept constant) include sophisticated software, BIM tools and technologies as has been explained in the empirical studies. They help ensure that any observed effects are truly due to the independent variables and not influenced by other factors.

Finally, when these problems are addressed, the aim of the HRB production in Lagos state which is improved cost, time, quality and safety will be achieved. This aim constitutes the Dependent variables which are the outcomes or responses that you measure or observe. They depend on the changes in the independent variables.

2.5 SUMMARY OF RESEARCH GAP

From the reviews above, the authors identified causative factors of project failure, commonly used project management tools, and technologies/software that can improve project performance (Ahuja et al., 2020; Liu et al., 2020). However, no author addressed the challenges peculiar to high-rise building production in Lagos State, nor did they identify the project management tools widely used in Lagos, or develop a framework for managing high-rise building construction in Lagos State (Eli, 2023).

Furthermore, an author highlighted the relationship between the four project management constraints/variables (time, cost, scope, and quality) (Kerzner, 2017). In this study, a regression analysis was conducted to demonstrate how project managers can balance these constraints for project success while maintaining quality and adherence to specifications.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 RESEARCH DESIGN

This study's research design serves as the overarching framework guiding the research process. A descriptive research design was employed, which involved a field survey approach to collect data. Consistent with the study's positivist philosophical underpinnings, emphasizing objectivity, the research primarily utilized quantitative data collection methods.

3.2. TYPES AND SOURCES OF DATA

The data used in the study were collected from two source, namely; the primary and secondary data.

1.2.1 Primary Data

The primary data are those sourced originally from the field as a primary source. The main primary data for this study are as follows;

i. **The challenges in high-rise building production in Lagos State, Nigeria:** Primary issues contributing to delays and cost overruns are: change orders, incomplete designs, underestimation, increased material costs, labour shortages, stop work orders, damage or theft of materials, poor weather conditions, safety hazards, poorly defined scope, inadequate preliminary studies, and resource allocation problems.

ii. **The characteristics of different management tools for HRB:** These include cost analysis, communication, estimation, time tracking, resource management, risk assessment, project analysis and reporting, web-based access, file sharing, issue tracking, task scheduling, collaboration, portfolio management, project planning, access control, document management, process development, ease of use, change management, and quality management

iii. The performances of project management tools for HRB production in Lagos State: The differences in the performance of the following PM tools were examined: BIM, Primavera, Ms-project, Earned Value Management, Project Evaluation and Review Techniques, Artemis view, Gantt Project, Work breakdown structure, Gantt chart, Open project, Network plan, Milestone chart, Business case, Critical path method, Redmine, Liquid Planner, Open workbench, Basecamp, Dot project and Assemble.

iv. Deficiencies of the project management tools for high-rise buildings production in Lagos State: The deficiencies include high maintenance costs, complexity of use, inability to manage complex projects, and lack of effective tracking and data sharing capabilities.

v. Technological tools that can help eliminate challenges in HRB production in Lagos state: The study proposes a framework as shown in figure 4.1

above; incorporating advanced tools such as Builder trend and Procure for change orders management, BIM + WBS for incomplete design issues, Project sight and Arch desk for accurate estimation, Neural Network in MATLAB for material cost management, SMARTBUILD for labor optimization, BIM + past project data for stop work orders, BIM + RFID for theft and hazard prevention, Baron Radars for weather prediction, BIM + EVA for scope definition, BIM + GIS for preliminary studies, and Runn for resource allocation.

3.2.2 Secondary Data

This study's secondary data were obtained through a comprehensive review of relevant literature, including textbooks, periodicals, magazines, newspapers, and previous theses. The secondary data are primarily presented in the literature review section of this study.

3.3 POPULATION OF THE STUDY

The population of this study comprises individuals involved in the construction of high-rise buildings in Victoria Island and Ikoyi. Specifically, the study targets the following professionals:Project Managers, Project Engineers, Supervisors, Contractors, Builders, Land Surveyors, Quantity Surveyors, Architects and Consultants

The population frame consists of 287 respondents from 41 completed high-rise buildings in Victoria Island (41 buildings x 7 professionals per building) and 119 respondents from 17 high-rise buildings in Ikoyi (17 buildings x 7 professionals per building), totaling 406 respondents.

3.4 Sample Size and Sampling Procedure

3.4.1 Sample Size

This refers to the number of people that were surveyed. The sample size was determined using the Taro Yamane formula as follows:

$$n = \frac{N}{1 + N(e)^2}$$

Where; n = sample size

N = population of the study (406), e = level of significance (0.05), 1 = constant.

Substituting the values, the sample size (n) is

There:

$$n = \frac{406}{1+406(0.05)^2}$$

$$n = \frac{406}{1+1.015} = \frac{406}{2.015} = 201.49$$

Approximately, n = 202. Base on the calculation, the sample size is approximately 202. Then add 10% for possible void and unreturned questionnaire; which implies 202 + 21 = 223, accept 224 as sample size.

The number of professionals that made up of 406 respondents from the 7 professionals are as distributed in their sample size.

Sample size distribution:

We have a total of 41 and 17 buildings in VI and Ikoyi respectively; each having 7 building professionals. Hence each professional in all the buildings involved is calculated as follows: {(41+17)/406} x 224/1 = 32

That is, 32 questionnaires each were given to the Project Managers, Project Engineers, Supervisors, Builders, Land Surveyors, Quantity Surveyors and Architects in the study area.

3.4.2 Sampling Procedure

Purposive sampling as the non-probability sampling technique was intentionally employed in this study by selecting specific individuals based on their expertise, knowledge and relevance to the research objectives. These individuals are among the targeted respondents.

3.5 INSTRUMENT OF DATA COLLECTION

The data collection instruments that was used in the study is structured questionnaire. The questionnaire for this study were in sections. The first section comprise of the respondents personal profile, namely; Respondents portfolio; Educational qualification; Professional Body; Age (years); years of experience; Marital status. The second and other sections are on the variables involved in the specific objectives of the study. The 5 points Linkert format of questionnaire was adopted for this study

3.6 METHOD OF DATA PRESENTATION

The data for objective 1 to 5 were presented using statistical tables only, while the profiles of the respondents were presented using tables, bar and pie charts.

3.7 METHODS OF DATA ANALYSIS

The data for this research was analyzed as follows;

1.) Relative Importance Index (RII) was used for ranking the data.

On the 5 Linkert scale format of the questionnaire, the ratings is as follows;

Strongly Agreed (SA) = 5; Agreed (A) = 4; Not Sure(NS) = 3; Disagreed (D) = 2; and Strongly Disagreed (SD) = 1.

Hence, RII = $(5n_5 + 4n_4 + 3n_3 + 2n_2 + n_1) / 5n$

Where;

n_5 = Strongly Agree (SA)

n_4 = Agreed (A)

n_3 = Not Sure (NS)

n_2 = Disagreed (D)

n_1 = Strongly Disagreed (SD)

In a related development, the 5 Likert scale format of the questionnaire, was used to assess the performances of the management tools for HRB production in Lagos State as follows, Highly Effective (HE) = 5; Effective (E) = 4; Slightly Effective(SE) = 3; Less Effective (LE) = 2; and Not Effective (NE) = 1.

Hence, RII = $(5n_5 + 4n_4 + 3n_3 + 2n_2 + n_1) / 5n$. Where;

n_5 = Highly Effective (HE)

n_4 = Effective (E)

n_3 = Slightly Effective(SE)

n_2 = Less Effective (LE)

n_1 = Not Effective (NE)

2.) Regression model was used:

Assumptions of the regression model was established thus: $Y= \beta0 + \beta n + \varepsilon$

For the multiple linear regression:

$Y= \beta0+\beta1+\beta2+\beta3+ \varepsilon$

For the simple regression model:

$\beta1$: Y= $\beta0 + \beta1 + \varepsilon$

$\beta2$: Y= $\beta0 + \beta2 + \varepsilon$

$\beta3$: $\beta1 = \beta0 + \beta3 + \varepsilon$

Where, the dependent variables Y = Performance, $\beta1$= Cost, $\beta2$=Time, $\beta3$=Scope and the intercept term, $\beta0$, represents the baseline performance when all other independent variables (cost, time, and scope) are zero and ε is the error term.

Simple linear regression was used to find the relationship between the independent variable $\beta1$= Cost, $\beta2$=Time, $\beta3$=Scope and tables were used to shows their relationships.

Similarly, a multiple linear regression was used to find the effects of Cost($\beta1$), Time ($\beta2$), Scope($\beta3$) on Performance (Y) by taking a linear combination of all the independent variables to form the multiple linear regression.

A graphical approach using box plot was used to check for outliers for the various linear combinations of the dependent and independent variables and it was discovered that there were no extreme outliers, extreme outlier and two minimal outliers.

A multivariate outlier test was carried out using the Mahalanobi Distance on the multiple linear regression model and the probabilities of the Mahalanobi values.

Moreover, a normality test was also carried out using the Shapiro Wilks test.

The histogram of the standardized regression residuals was also examined for normal distribution.

3.) Kruskal-Wallis H test was used to assess the characteristics of the various project management tools

4.) Mann-Whitney U test was used to compare the mean performance of different project management tools for HRB production in Lagos State with others project management tools. The normal distribution approximates the Mann-Whitney U statistic T as:

$$Z = \frac{|R - \mu| - 0.5}{\sigma} \qquad (3.3)$$

Given H_0,

$$\mu = \frac{m(N+1)}{2} \qquad (3.4)$$

and

$$\sigma^2 = \frac{mn(N+1)}{12} \qquad (3.5)$$ respectively.

R is the sum of ranks for smaller sample size (n), m is the larger of sample sizes, $N = m + n.$

A table of critical values corresponding to Mann-Whitney U statistic is contained in any standard text. The decision is to reject the null hypothesis if p-value is less than the level of significance (0.05).

5.) Kruskal-Wallis H test was used to assess the significant difference in deficiencies of the project management tools for high-rise buildings production in Lagos State .

6.) Kruskal-Wallis H test was be used to determine the in-dependency between the technologies tools and the level of impact that can help eliminate challenges in HRB production in Lagos state. The test statistic T or H, which corresponds to the Chi-square value, is computed as;

$$T = H = \frac{n-1}{12} \sum_{i=1}^{k} \frac{n_i(\overline{R}_i - E_R)^2}{\sigma_R^2} \qquad (3.6)$$

Where n is the total sample size;

n_i is the number of cases in group i;

$\overline{R}_i$ is the mean rank sum in group i;

$E_R = \frac{n+1}{2}$ is the expected value of the rankings;

$\sigma_R^2 = \frac{n^2-1}{12}$ is the rank variance.

The decision rule is to reject the null hypothesis if H ≥ $\chi^2_{(k-1)}$, where k is the degrees of freedom. However, for the sake of this work, the p-value generated from the IBM SPSS was used for decision making. Thus, the null hypothesis is rejected if p-value is less than the level of significance (0.05).

3.7.1 The philosophical basis for the methodology:

This study is grounded in the positivist research paradigm, which emphasizes the use of scientific methods to uncover objective knowledge about the world. The positivist approach is suitable for this study, as it seeks to identify causal relationships between variables and predict outcomes through the use of statistical analysis.

The study's methodology is also informed by the pragmatist philosophy, which emphasizes the importance of practical application and problem-solving. The development of a framework for effective use of project management tools in high-rise building production is a practical problem that requires a solution-oriented approach.

The use of statistical analysis, including Relative Importance Index (RII), regression analysis, Kruskal-Wallis H test, and Mann-Whitney U test, reflects a commitment to objectivity and rigor in the research process. These methods allow for the identification of patterns and relationships in the data, which can inform the development of the framework.

Furthermore, the study's focus on the development of a framework that can be applied in practice reflects a pragmatic approach to research, which prioritizes the generation of knowledge that can be used to improve real-world outcomes.

- Epistemological Assumptions:

This study assumes that knowledge about the effectiveness of project management tools in high-rise building production can be obtained through empirical observation and statistical analysis. The study also assumes that the relationships between variables can be modeled and predicted using statistical techniques.

- Ontological Assumptions:

This study assumes that reality is objective and can be studied using scientific methods. The study also assumes that the effectiveness of project management tools is a measurable construct that can be studied using quantitative methods.

- Research Paradigm:

The study is situated within the positivist research paradigm, which emphasizes the use of scientific methods to uncover objective knowledge about the world. The study's methodology reflects a commitment to objectivity, rigor, and practical application.

3.8 SOFTWARE

The Statistical Package for Social Sciences SPSS (IBM SPSS version 29.0.1.0) was used to perform the analysis of this study. The IBM SPSS was used for descriptive analysis to assess the nature of the data and develop the respondents' demographic characteristics. Also IBM SPSS was also employed for the nonparametric inferential statistical techniques employed to achieve the hypotheses of this study.

3.9 VALIDITY AND RELIABILITY OF DATA COLLECTION INSTRUMENT

Validity answers the question as to whether a research instrument such as a questionnaires or interview actually measures what it was intended to measure or whether its scores have meaning for a participant (Kouzes & Posner, 1995;

Saunders et al., 2012). To ensure the research findings are valid, the literature review will be used as a guide. As discussed in the literature review, the reviewed literature is directly related to the research objectives and therefore using this as a guide helped obtain the necessary data from the respondents. This ensures that the research instruments being used are appropriate for this study and questionnaire questions reflect the topic under study (Saunders et al., 2012). The research instruments (questionnaires) are reviewed by experts in the field, as Huck and Cormier (1996) and Saunders et al. (2012) advocate. Further, the study's data instruments have been adopted from previous studies, with minimal alterations made to meet the requirements of this research.

Reliability is the degree to which a result can repeat itself over time. In other words reliability refers to consistency (Saunders et al., 2012; Bryan, 2012). Joppe (as cited in Golafshani, 2003) defines reliability as: "…The extent to which results are consistent over time and an accurate representation of the total population under study and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable". Achieving accuracy is crucial in research, and reliability is essential to getting it right. According to Leedy and Ormrod (2004), reliability guarantees consistent measurements when studying an unchanging variable - similar to how a trustworthy thermometer always shows the same temperature reading.

Cooper and Schindler (2001) underscore that validity is equally vital. A well-designed sample must accurately reflect the target population, capturing its characteristics faithfully. For example, a reliable questionnaire is one that will give the same results or answers from the same sample over different periods. Data collection will be piloted before the full collection of data occurred. Saunders (2009) argues that "Prior to using your questionnaire to collect data it should be pilot tested. The essence of the pilot test is to refine the questionnaire so that the respondents will have no problem answering the questions and there will be no problem in recording the data". In other words and according to (Sekaran, 2003)the questionnaire is pre-tested to establish that the questions are fully comprehensible and are understood by the respondents, in order to ensure the soundness and suitability of the research instruments. In the questionnaire pilot, the analysis of 25 questionnaires will be made using Cronbach alpha. Cronbach's alpha allows the researcher to measure the reliability of different variables. It consists of estimates of how much variation in scores of different variables is attributable to chance or random errors (Selltiz et al., 1976). As a general rule, a coefficient greater than or equal to 0.7 is considered acceptable and a good indication of construct reliability (Nunnally, 1978). All the necessary amendments will be made to ensure that the questionnaire is unambiguous for easy response.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSION OF FINDINGS

4.1 DATA PRESENTATION

Total questionnaire distributed = 224 (sample size).

Total returned = 208.

Percentage returned = (208/224) × 100 = 93% (excellent)

Table 4.1: Profile of the respondents

Table 4.1a: Gender of the respondents

Gender	**Frequency**	**Percentage**
Male	191	91.8

Female	17	8.2
Total	208	100

Source: Fieldwork, 2023

Table 4.1b: Academic Qualification of the respondents

Academic Qualifications	Frequency	Percentage
Ph.D.	61	29.3
M.Sc.	52	25
B.Sc./HND	30	14.4
Diploma	53	25.5
Others	12	5.8
Total	**208**	**100**

Source: Fieldwork, 2023

Table 4.1c: Position of the respondents

Position	Frequency	Percentage
Architects	39	19
QSV	24	12
Project Managers	30	15
Engineers	50	24
Supervisors	35	17
Builders	21	10
Land Surveyors	10	5
Total	**208**	**100**

Source: Fieldwork, 2023

Table 4.1d: Respondents Years of Experience

Years of Experience	Frequency	Percentage
1-5	6	2.9
6-10	49	23.5
11-15	58	27.9
16-20	45	21.6
Above 20	50	24.1
Total	**208**	**100**

Source: Fieldwork, 2023

Table 4.1e: Marital Status of the respondents

Marital Status	**Frequency**	**Percentage**
Single	7	3.4
Married	201	96.6
Total	208	100

Source: Fieldwork, 2023

PROJECT MANAGEMENT CONSTRAINTS THAT AFFECT THE PERFORMANCE OF HIGH-RISE BUILDING (HRB) PROJECTS IN LAGOS STATE.

TABLE 4.2: PROJECT CONSTRAINTS/VARIABLES FROM FIELD: (For Pictures of some of the projects see appendix-page 144-159)

PROJECT CONTRAINTS VARIABLE DATA FROM FIELD							
	PILING WORK	QTY	UNIT	SPI	% COMPLETION	PROJECT DURATION (DAYS)	BAC
	Allow for all work in connection with piling work including all necessary equipment for complete execution and demobilization after completion			Dependent Variables	Independent Variables		
Sn	Task & Locations			Performance	Scope	Time	Cost
1	19B Cooper Road Ikoyi	165	piles	0.75	79%	45	76,312,500.00
2	7, Reeves Road Ikoyi	158	piles	0.80	88%	45	75,840,000.00
3	4 Bourdillon (Ikoyi)	202	piles	0.95	97%	57	126,492,400.00
4	Kingsway Tower (Ikoyi)	219	piles	1.00	100%	64	137,137,800.00
5	Cuddle Integrated High-Rise Development (Ikoyi)	221	piles	1.11	100%	70	139,654,037.44
6	4 Bourdillon (Ikoyi)	198	piles	0.79	77%	61	118,800,000.00
7	Eko Tower II (Victoria Island)	220	piles	0.95	98%	66	143,000,000.00
8	Champagne Pearl Tower	222	piles	1.11	100%	70	145,611,818.18
9	Promontory (Ikoyi)	175	piles	1.00	97%	50	87,500,000.00
10	Orchard House (Ikoyi)	201	piles	1.11	100%	54	114,570,000.00
11	Astoria (Ikoyi):	211	piles	1.41	100%	76	120,270,000.00
12	Roberts House (Ikoyi):	231	piles	1.11	100%	64	131,670,000.00
13	Sussex Place (Victoria Island)	222	piles	1.11	100%	66	126,540,000.00
14	WEMA Tower	220	piles	1.11	100%	77	125,400,000.00
15	Stallion Tower	295	piles	1.41	100%	80	168,150,000.00
16	Sapetro Tower	287	piles	1.11	100%	55	163,590,000.00
17	Nestoil Tower (Victoria Island, Lagos)	275	piles	1.11	100%	51	156,750,000.00
18	Sky 55	265	piles	1.11	100%	60	151,050,000.00
19	Black Pearl Tower	255	piles	1.11	100%	67	145,350,000.00
20	Champagne Pearl Tower	208	piles	1.11	100%	66	118,560,000.00
21	NECOM House	266	piles	1.11	100%	65	151,620,000.00
22	Champagne Pearl Tower	190	piles	1.11	100%	55	108,300,000.00
23	CBN Lagos	245	piles	1.11	100%	53	139,650,000.00
24	Lagos Continental Hotel	208	piles	1.41	100%	50	118,560,000.00
25	Azuri One, Azuri Towers	195	piles	1.11	100%	47	111,150,000.00
26	Mixed-Use High-Rise Building	188	piles	1.21	100%	50	107,160,000.00
27	Eko Court II	178	piles	1.15	100%	48	174,000,000.00
28	Eko Court Complex	188	piles	1.31	100%	76	155,000,000.00
29	Lucrezia by Sujimoto	190	piles	1.21	100%	70	120,000,000.00
30	Ocean Parade Towers	200	piles	1.15	100%	66	150,000,000.00
	Source: Fieldwork, 2023						

THE PERFORMANCE OF DIFFERENT PROJECT MANAGEMENT TOOLS FOR HRB PRODUCTION IN LAGOS STATE.

TABLE 4.3: RELATIVE IMPORTANCE INDEX AND RANKING.

	The project management tools for HRB production in Lagos State.	SA 5	A 4	NS 3	D 2	SD 1	RII	RANK
1.	BIM	490	320	69	10	2	.86	1
2.	Primavera	360	272	201	0	1	.80	2
3.	Ms-project	385	276	156	16	2	.80	2
4.	Earned Value Management	335	248	153	36	10	.75	4
5.	Project Evaluation and Review Techniques	355	216	90	62	22	.72	5
6.	Artemis view	225	244	228	40	6	.71	6
7.	Gantt Project	305	196	153	34	30	.69	7
8.	Work breakdown structure	170	268	162	80	13	.67	8
9.	Gantt chart	255	216	102	80	29	.66	9
10.	Open project	225	168	168	84	23	.64	10
11.	Network plan	280	56	228	68	28	.63	11
12.	Milestone chart	215	260	69	34	60	.61	12
13.	Business case	160	136	258	8	52	.59	13
14.	Critical path method	225	88	135	120	36	.58	14
15.	Redmine	160	48	300	60	34	.58	14
16.	LiquidPlanner	90	56	351	90	14	.58	14
17.	Open workbench	170	180	69	130	41	.57	17
18.	Basecamp	115	268	36	112	50	.56	18
19.	Dot project	165	100	234	16	64	.56	18
20.	Assembla	25	76	390	28	40	.54	20

Source: Fieldwork, 2023

THE DEFICIENCIES OF THE PROJECT MANAGEMENT TOOLS USED FOR HIGH-RISE BUILDINGS PRODUCTION IN LAGOS STATE.

TABLE 4.4: RELATIVE IMPORTANCE INDEX AND RANKING.

	The deficiencies of the project management tools used for high-rise buildings production in Lagos State	SA 5	A 4	NS 3	D 2	SD 1	RII	RANK
1.	Needs supportive tools	355	280	195	2	1	.80	1
2.	Not good for high-rise buildings	380	276	162	6	6	.80	1
3.	High maintenance and implementation cost	365	272	177	2	7	.79	3
4.	Less tracking of projects.	400	240	99	64	3	.78	4
5.	Impossibility in managing complex projects	350	300	105	36	10	.77	5
6.	Inability to handle crashing tasks	380	244	120	42	10	.77	5
7.	Complex of use	335	296	99	14	27	.74	7
8.	Inability to represent valuable information	305	252	96	94	5	.72	8
9.	Waste time	175	220	180	80	18	.65	9
10.	Non-prediction of project uncertainty	335	280	162	28	3	.62	10
11.	High rate of mistakes during use	415	44	69	22	80	.61	11
12.	Hindrance in data sharing	270	92	129	90	43	.60	12
13.	Lack of logical representation of projects	170	56	201	140	23	.57	13

Source: Fieldwork, 2023

CONSTRUCTION TECHNOLOGY TOOLS THAT CAN HELP ELIMINATE CHALLENGES IN HRB PRODUCTION IN LAGOS STATE

TABLE 4.5: RELATIVE IMPORTANCE INDEX AND RANKING.

	Construction technology tools that can help	HE	E	SE	LS	NE	RII	RANK

	eliminate challenges in HRB production in Lagos state	5	4	3	2	1		
1.	BIM environment + cost estimation software	375	264	156	18	6	.79	1
2.	BIM + Earned Value Analysis (EVA)	350	264	150	26	9	.77	2
3.	BIM + Critical Path Method (CPM)	335	264	180	12	9	.77	2
4.	Builder trend	335	312	90	44	11	.76	4
5.	Procore	300	288	144	42	8	.75	5
6.	Archdest	305	272	162	36	7	.75	5
7.	Projectsight	315	228	165	64	1	.74	7
8.	BIM + cost-based progress curves	295	256	162	58	2	.74	7
9.	BIM + GIS	325	216	129	66	13	.72	9
10.	BIM + digital programming	320	224	102	102	3	.72	9
11.	BIM + 3D imaging technologies	285	256	153	46	13	.72	9
12.	4D BIM model	300	244	150	40	17	.72	9
13.	Neutral Network in MATLAB	315	244	114	54	19	.72	9
14.	SMARTBUILD	285	260	135	38	22	.71	14
15.	Runn	235	224	174	32	31	.69	15
16.	BIM + 4-Dimensional Augment Reality (AR)	280	260	54	78	30	.68	16
17.	BIM + Radio Frequency Identification Device (RFID)	170	268	45	148	18	.62	17
18.	Baron radars	225	136	105	90	49	.58	18
19.	BIM + past data of completed projects	115	144	54	120	71	.48	19

Source: Fieldwork, 2023

THE CHARACTERISTICS OF PROJECT MANAGEMENT TOOLS FOR HIGH-RISE BUILDINGS PRODUCTION

TABLE 4.6: RELATIVE IMPORTANCE INDEX AND RANKING

	Ranking of the characteristics of project management tools for high-rise buildings	SA 5	A 4	NS 3	D 2	SD 1	RII	RANK

	production.							
1.	Cost analysis	395	320	48	64	1	.80	1
2.	Communication tool	340	284	207	0	0	.80	1
3.	Estimating	390	216	174	36	0	.79	3
4.	Time tracking.	350	296	135	20	9	.78	4
5.	Resource management	375	248	153	26	7	.78	4
6.	Risk assessment	355	268	180	4	8	.78	4
7.	Project analysis and report	390	240	126	54	1	.77	7
8.	Web based	335	292	108	64	0	.77	7
9.	File sharing	335	264	174	28	3	.77	7
10.	Issue tracking	365	220	177	12	15	.76	10
11.	Task scheduling	340	312	69	34	22	.75	11
12.	Collaboration	285	292	180	8	14	.75	11
13.	Portfolio management	325	264	156	8	21	.74	13
14.	Project planning	350	280	0	62	37	.70	14
15.	Access control	270	104	315	10	18	.69	15
16.	Document management	280	280	36	60	40	.67	16
17.	Process development	215	228	147	102	8	.67	16
18.	Ease of use	170	316	96	64	31	.65	18
19.	Change management	240	220	63	60	42	.60	19
20.	Quality management	65	184	201	134	15	.56	20

Source: Fieldwork, 2023

4.2 ANALYSIS AND DISCUSSION OF FINDINGS

This section presents the analysis of data collected by the researcher for the study, utilizing a rating scale. The results are organized according to the research hypotheses. The data were analyzed graphically to provide profile information and questionnaire distribution rates, and inferentially to test the research hypotheses.

4.2.1 Hypothesis One

H_{01}:The project management constraints, including cost, time, and scope, have no significantly influence on the performance of HRB production projects in Lagos State.

4.2.1.1 Analyses

Table 4.7: Summary Result of Regression Model

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Cost[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Performance

Table B11: **Source:** Extracted from SPSS Output

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.0.52	0.2704	0.323	.16211

a. Predictors: (Constant), Cost

Table B12: **Source:** Extracted from SPSS Output

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.3214.64	1	.212.33	.9.67	.0.0023
	Residual	.736	28	.026		
	Total	.736	29			

a. Predictors: (Constant), Cost

b. Dependent Variable: Performance

Table B13: **Source:** Extracted from SPSS Output

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.105	.030		36.305	.000
	Cost	.2.015	.000	.010	.055	0.000

a. Dependent Variable: Performance

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Time[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Performance

Table B21: **Source:** Extracted from SPSS Output

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.441[a]	.194	.166	.14551

a. Predictors: (Constant), Time

Table B22: **Source:** Extracted from SPSS Output

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.143	1	.143	6.758	.015[a]
	Residual	.593	28	.021		
	Total	.736	29			

a. Predictors: (Constant), Time

b. Dependent Variable: Performance

Table B23: **Source:** Extracted from SPSS Output

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.687	.163		4.208	.000
	Time	.007	.003	.441	2.600	.015

a. Dependent Variable: Performance

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Scope[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Performanc

Table B31: **Source:** Extracted from SPSS Output

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.717[a]	.514	.497	.11299

a. Predictors: (Constant), Scope

Table B32: **Source:** Extracted from SPSS Output

ANOVA[b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.379	1	.379	29.650	.000[a]
	Residual	.357	28	.013		
	Total	.736	29			

a. Predictors: (Constant), Scope

b. Dependent Variable: Performance

Table B33: **Source:** Extracted from SPSS Output

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.800	.350		-2.282	.030
	Scope	.019	.004	.717	5.445	.000

a. Dependent Variable: Performance

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Scope, Cost, Time	.	Enter

a. All requested variables entered.

b. Dependent Variable: Performance

Table B41: **Source:** Extracted from SPSS Output

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.756[a]	.571	.522	.11013

a. Predictors: (Constant), Scope, Cost, Time

Table B42: **Source:** Extracted from SPSS Output

ANOVA[b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.421	3	.140	11.558	.000[a]
	Residual	.315	26	.012		
	Total	.736	29			

a. Predictors: (Constant), Scope, Cost, Time

b. Dependent Variable: Performance.

Table B43: **Source:** Extracted from SPSS Output

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.839	.343		-2.450	.021
	Cost	.000	.000	-.081	-.621	0.023

Time	.004	.002	.251	1.833	.0024
Scope	.017	.004	.644	4.754	.000

a. Dependent Variable: Performance

From the regression analysis in **Table B_{12},** the correlation coefficient between **performance and cost** is strongly positively correlated, with a value of 0.52. Cost accounting for 27 percent variance in the dependent variable (performance).

The ANOVA table (in Table B_{13}) reveals a significant F-ratio of 9.67, with a P-value of 0.0023.The adjusted R-squared value provides an estimate of what to expect the R-square value to be if the study was conducted again with a new 30 cases. In this study, the value is 0.323 (See Table B_{12}).

The unstandardized beta co-efficient in the regression model is also significant with a p-value of 0.000. This means that cost is significant to the prediction of performance in the simple linear regression model. Similarly, **for scope and time**, there is a strong positive correlation. This can be seen in Tables **B_{32}** and **B_{22}** , with a values of 0.717 and 0.441 respectively; with scope and time explaining 51.4% and 19.4% variance respectively in the dependent variable (performance). The ANOVA table in **Table B_{33} and B_{23}** gave a significant F-ratio of 29.650, 6.758 with a P-value of 0.000, 0.015 for scope and time respectively. Time is significant in predicting performance in the model. The same applies to **cost and scope.**

Moreover considering the multiple linear regression model-**Table B_{42}**, the multiple correlation has a value of 0.756, which indicates a strong positive correlation between performance (dependent variable) and the independent variables (cost, time and scope). The R-squared value, being 0.571, explaining about 57.1% of variance in the dependent variable (performance). The more variables are entered into the model, the better the prediction of performance.The null hypothesis is rejected and we conclude that there is a statistical significant relationship, that is when performance is considered separately as a dependent variable.

4.2.2 Hypothesis Two

H_{02}: there is no significant difference in the performance of different project management tools for HRB production in Lagos State.

4.2.2.1 Analyses

Table 4.8: Results of the Mann-Whitney Test

		Decision
Mann-Whitney	114.00	Reject the null hypothesis
p-value	0.032	

Source: Extracted from SPSS Output

Since the p-value 0.032 is less than 0.05 reject the H_0. Thus, it can be concluded that there is significant difference in the performance of different project management tools for HRB production in Lagos State with other project management tools.

4.2.2.2 Explanation of Findings

The result using the Mann-Whitney U test concluded that there is significant difference in the performance of different project management tools for HRB production in Lagos State as shown on table 4.3 with the project tools proposed on this study as shown on table 4.5.

4.2.3 Hypothesis Three

H_{03}:the deficiencies of the project management tools used for high-rise buildings production in Lagos State do not differ significantly from each other.

4.2.3.1 Analyses

Table 4.9:Independent Samples Kruskal Wallis Test Summary for Deficiencies of the Project Management Tools

		Decision
Total N	2704	Reject the null hypothesis
Test Statistic	221.699	
Degree of Freedom	12	
p-value	< 0.001	

Source: Extracted from SPSS Output

Since p-value (< 0.001) is less than the level of significance 0.05, reject the null hypothesis, concluding that the deficiencies of the project management tools used for high-rise buildings production in Lagos State differ significantly from each other.

4.2.3.2 Explanation of Findings

The result using the Kruskal-Wallis H shows that the p-value (< 0.001) is less than the level of significance (0.05), which means that the null hypothesis is rejected. Hence, this implies that each project management tool used in Lagos state has its own deficiency which differs significantly with others. The project management tools used in Lagos state need supporting tools to perform well, therefore, they are not good for high-rise buildings these deficiencies ranked first with the Relative Importance Index of 0.80 each. They also need high maintenance and implementation cost; and Less tracking of projects, These deficiencies are ranked 3rd and 4th. The management tools used in Lagos state cannot be used in managing complex projects or handling crashing tasks. these shortcomings are tied at 5th with the Relative Importance Index of 0.77 each. They are complex to use; they cannot represent valuable information; and the waste time. These pitfalls are ranked 7th, 8th and 9th respectively. They cannot predict the uncertainty of a project; high rate of mistake during use and hindrance in data sharing are ranked 10th, 11th, and 12th respectively, with the relative Important Index of 0.62, 0.61 and 0.60 respectively. Lack of logical representation of projects is ranked last with the Relative Importance Index of 0.57.

4.2.4 Hypothesis Four

H_{04}:there is no significant difference between the performances of the technologies that can help eliminate challenges in HRB production in Lagos state.

4.2.4.1 Analysis

Table 4.10: Independent Samples Kruskal Wallis Test Summary for HRB production

		Decision
Total N	3952	Reject the null hypothesis
Test Statistic	255.726	
Degree of Freedom	18	
p-value	< 0.001	

Source: Extracted from SPSS Output

The result shows that the p-value (<0.001) is less than the level of significance (0.05), which means that the null hypothesis is rejected. Hence, this implies that there is significant difference between the performances of the technologies that can help eliminate challenges in HRB production in Lagos state.

4.2.4.2 Explanation of Findings

The result using the Kruskal-Wallis H testshows that the p-value (<0.001) is less than the level of significance (0.05), which means that the null hypothesis is rejected. This implies that there is significant difference between the performances of each technology that can help eliminate challenges in HRB production in Lagos state.

4.2.5 Hypothesis Five

H_{05}: the characteristics of the various project management tools do not vary significantly in their effect on the production of high-rise building in the area.

4.2.5.1 Analyses

Table 4.11: Independent Samples Kruskal Wallis Test Summary for various Project Management Tools

		Decision
Total N	41600	Reject the null hypothesis
Test Statistic	228.495	
Degree of Freedom	19	
p-value	< 0.001	

Source: Extracted from SPSS Output

The result reveals that the Kruskal Wallis test statistic value is 228.495with a p-value (< 0.001) that is less than the level of significance 0.05. Hence, leading to the rejection of the null hypothesis, concluding that the characteristics of the various project management tools do vary significantly in their effect on the production of high-rise building in the area.

4.2.5.2 Explanation of Findings

The result using the Kruskal Wallis test statistic shows that the (< 0.001) is less than the level of significance 0.05, thus the null hypothesis was rejected. This implies that each management tool for the production of high-rise building has a unique characteristic that differ from others ranking from 1 to 20 as it is shown on table 4.3. The best characteristics of a good project management tool are: cost analysis and ability to communicate with both human and machines, and they are ranked 1st and second respectively. Another important characteristic to look for in a project management tool is their ability to estimate both time and cost of the project and this characteristic is ranked 3rd. Furthermore, the ability of a project management tool to track time; manage resources and assess risk are ranked 4th with the Relative Important Index of 0.78 respectively. Again, project analysis and report; web based; and file sharing are another important characteristics of a good project management tool and are ranked 6th with the Relative Important Index of 0.77 respectively. Issue tracking is ranked 10th on the list. Task scheduling and collaboration are tied together at the 11th position with the Relative Importance Index of 0.75. portfolio management, project planning, and access control are another characteristics of project management tools and they are ranked 13th , 14th and 15th respectively with the Relative Importance Index of 0.74, 0.70, and 0.69 respectively. Document management and process development are the characteristics of management tools that are tied at the 16th position with the Relative Importance Index of 0.67 respectively. A good project management tool should be ease to use and able to handle changes. These characteristics are ranked 18th and 19th with a Relative Importance Index of 0.65 and 0.60 respectively. Finally, a good project management tool should be able to manage quality of work. Though, this is ranked 20th out of 20 with the Relative Importance Index of 0.56.

4.2.6 Discussion of Findings

The study's results reveal significant insights into project management tools and techniques for high-rise building production. The findings indicate that project failure can result from various factors, including resource limitations, scope changes, communication challenges, and inadequate planning. The main reasons for project failure, as identified by the Project Management Institute (PMI, 2012), include underestimation of project preparation, lack of executive sponsorship support, inaccurately set project benefits, and failure to manage changes.

The study's statistical analysis shows that there is a significant difference in the performance of different project management tools for HRB production in Lagos State (p-value = 0.032 < 0.05). Additionally, the deficiencies of project management tools used for high-rise buildings production differ significantly from each other (p-value < 0.001). The characteristics of various project management tools also vary significantly in their effect on high-rise building production (p-value < 0.001).

These findings align with existing literature, which highlights the importance of robust and adaptable project management tools and techniques (PMTTs) in the construction industry (Cheng, 2005; Muhammad, 2015). A good project management tool should possess characteristics such as task scheduling, resource management, collaboration, time tracking, estimating, and risk assessment.

The study's implications suggest that project managers should carefully select and utilize project management tools to mitigate risks and improve project success. However, the study's limitations include the potential complexity of project management tools, such as Gantt charts, which can become difficult to manage with a large number of activities (Ballesteros-Pérez, 2018). Nevertheless, some software tools, such as Mavenlink, Wrike, Smartshet, and AceProject, can help manage this complexity (Mubarak, 2003).

Overall, the study's findings contribute to the understanding of project management tools and techniques for high-rise building production, highlighting the need for effective project management to ensure project success.

4.2.8 Framework for the use of project management tools in HRB construction

Each management tool as presented in Table 4.5 has its unique function of eliminating risk and serves a purpose different from each other as described on the framework in figure 4.1.

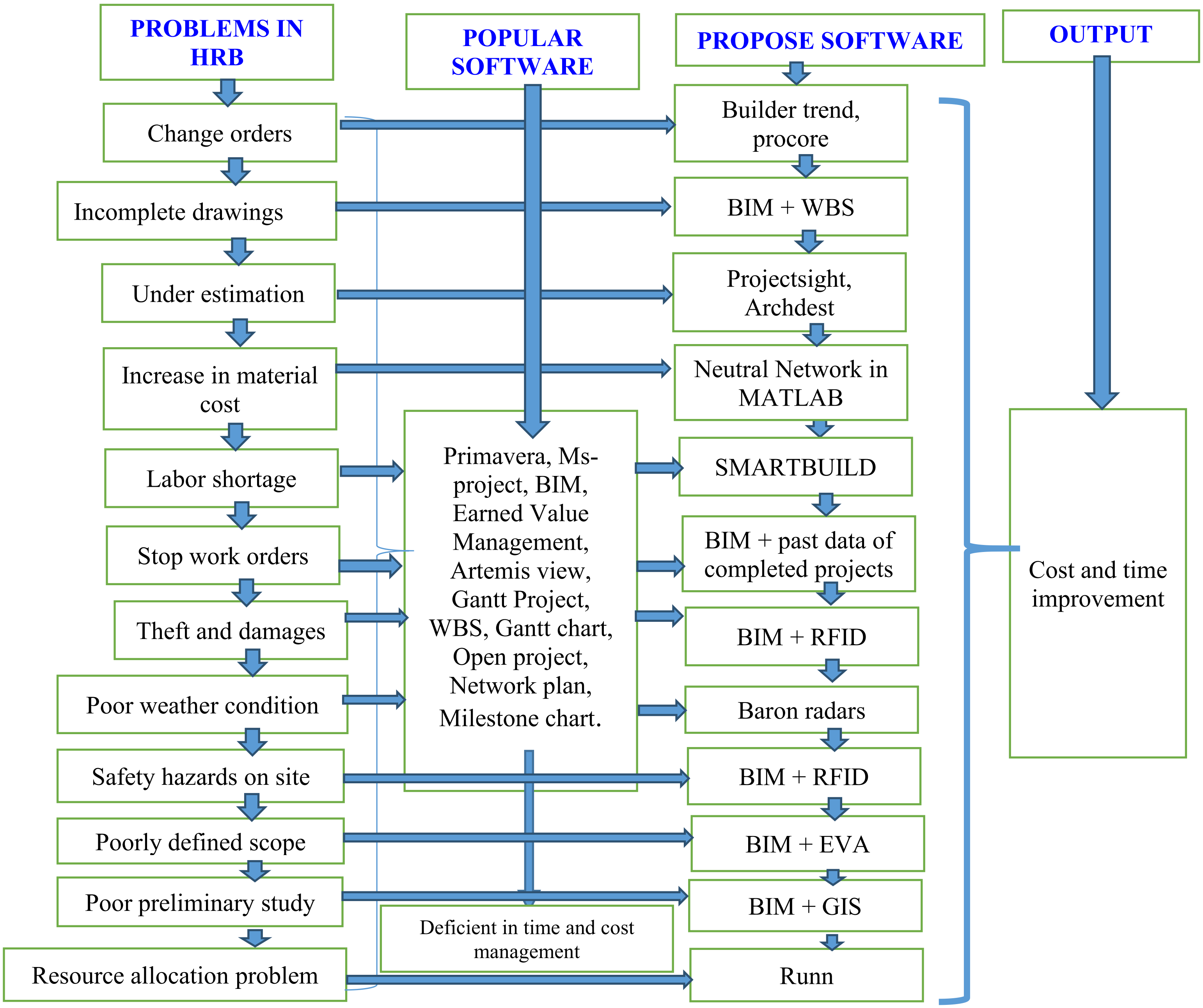


Figure 4.1: Proposed Framework for the Study (Source: Field Study, 2023)

(See health warning on the next page of the above of the above hypothetical framework)

Important Notice (health warning on the proposed framework):

The framework for effective use of project management tools in high-rise building production in Lagos State, Nigeria, is intended to provide general guidance and support for project managers. While every effort has been made to ensure the accuracy and relevance of the framework, it is essential to note that:

- The framework is based on research conducted in Lagos State, Nigeria, and its applicability to other contexts may be limited.
- The effectiveness of the framework depends on various factors, including the specific project requirements, team dynamics, and organizational culture.
- The framework should not be considered a substitute for professional judgment, expertise, and experience in managing high-rise building projects.
- Users of the framework should exercise caution and adapt it to their specific needs and circumstances.

By using this framework, project managers acknowledge that they are responsible for exercising their own professional judgment and discretion in applying the guidance provided.

The framework was developed to help the stakeholders in the construction study who specialize in high-rise building development to avert the risk of time and cost overruns. In the framework, the major causes of time and cost overrun in Lagos state were identified using the semi structured questionnaires on the stakeholders. The major problems were: change orders, incomplete drawing, underestimation, and increase in material cost. Others are; labour shortage; stop work orders; theft and damages to plant, equipment & materials; and poor weather condition. Also included in the list are: safety hazards on the site; poorly defined scope of work; poor preliminary study and resource allocation problem.

However, in Lagos state, software used for the construction management are used without recount to a particular problem. Rather, they are used holistically for the entire construction project and for any problem that arises. These software popularly used in Lagos for the management of high-rise building are; Primavera, Ms-project, BIM, and Earned Value Management. Moreover, Artemis view, Gantt Project, WBS, and Gantt chart are also the leading software used in the management of construction activities in Lagos state. Lastly, Open project, Network plan and Milestone chart are also adopted.

Despite the application of these software in the construction of high-rise buildings, cost and time overrun persist because they are deficient in time and cost management. Therefore, the framework proposed software for the definite problems identified as follows; for change order management, Builder trend and Procore is proposed for its identification and management. Secondly, for incomplete drawing problems, this framework proposes the combination of the Building Information Modelling with the Work Breakdown Structure in order to identify the components or quantities that have been omitted as a result of time and cost constraints or incompetency of the designers or any other problem that might result into incomplete drawings.

Again, for underestimation, this framework proposes the use of Project sight, and Archdest for cost estimation of projects. These software have the potentials to identify the components of works that have been under quantified or omitted. For Increase in material cost, the framework proposes the adoption of Neutral Network in MATLAB for the prediction of building materials cost. These software can predict the cost of building materials for at least, three to five years, using the prices of the previous years. However, for the prediction to be complete, the results are validated using Linear Trend Progression which is ran on Excel. The validated results are reliable for cost estimation of construction projects that are bound to last for more than a year, keeping the price increase in view.

In the same vain, the problems cause as a result of Labor shortage can be managed using SMARTBUILD. The delays and cost overrun caused by Stop work orders can be eliminated by using BIM and past data of completed projects in a similar geographical area. This will help in the identification of the requirements for the completion of the proposed work without interruption. Theft and damages can be reduced by the attachment of the Radio Frequency Identification (RFID) tag to materials, tools and machines for an effective tracking on and outside the construction sites.

The problem of delays caused by Poor weather condition can be eliminated by the use of Baron Radars for the prediction of weather condition. This helps in the scheduling of works considering the atmospheric elements. Safety hazards on site can be reduced by the use of the Radio Frequency Identification (RFID) to identify risk on site before they occur, when these risks are identified and taken care of, the hazards are eliminated. Problems resulting from Poorly defined scope can be eliminated by the use of BIM and Earned Value Analysis (EVA). The problem of Poor preliminary study are eliminated using BIM with a Geographic Information System (GIS) to collect information about the proposed site. Resource allocation problem can be handle using the Runn.

The principles underlying the framework are as follows;

1. There is no software that can handle all the risks identified in the study at the same time, because every risk is unique and needs a unique management tool.

2. All the risks are not present in the site at the same time therefore, when identified, it should be managed using the appropriate tool.

3. This framework can be applied to any other form of construction and outside the study area provided that the problems identified are identical to those on the framework.

It is worthy of note that the regression analysis provided further insights into the relationships between cost, time, scope, and performance, aiding decision-making and project management.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY OF MAJOR FINDINGS

In an effort to develop a framework for mitigating delays, cost overruns and risk in HRB construction, the summary of findings are as follows;

5.1.1 Identification of Major Factors: The study identified major problems in HRB construction in Lagos State, including change orders, incomplete designs, underestimation, increased material costs, labor shortages, stop work orders, material damage or theft, poor weather, safety hazards, poorly defined scope, inadequate preliminary studies, and resource allocation issues.

5.1.2 Characteristics of Effective Project Management Tools: It analyzed the characteristics of effective management tools to address these issues, highlighting features such as project planning, cost analysis, communication, estimation, time tracking, resource management, risk assessment, project analysis and reporting, web-based access, file sharing, issue tracking, task scheduling, collaboration, portfolio management, access control, document management, process development, ease of use, change management, and quality management.

5.1.3 Performance of Current Tools: The analysis revealed that the performance of current management tools in Lagos differs from the proposed tools aimed at eliminating delays and cost overruns.

5.1.4 Deficiencies of Existing Tools: Deficiencies in existing tools include lack of support for HRBs, high maintenance costs, poor project tracking, inability to manage complex projects, difficulty handling task crashes, complexity of use, inadequate information representation, time wastage, inability to predict project uncertainty, high error rates, data sharing hindrances, and lack of logical project representation.

5.1.5 Proposed Tools and Framework: To address these issues, the study proposed a framework incorporating tools like Builder trend and Procure for change order management, BIM + WBS for incomplete designs, Project sight and Arch desk for underestimation, Neural Network in MATLAB for material cost increases, SMARTBUILD for labor shortages, BIM + past project data for stop work orders, BIM + RFID for damage, theft, and hazard prevention, Baron radars for weather prediction, BIM + EVA for poorly defined scope, BIM + GIS for preliminary study issues, and Runn for better resource allocation.

5.1.6 Impact of Constraints on Project Performance: Effective constraint management ensures successful project delivery, meeting stakeholders' expectation and maintaining team morale.

5.2 RECOMMENDATIONS

To effectively address the identified problems in HRB construction in Lagos State, it is important to seek support from stakeholders and the government thus:

i. **Possible Adoption by Project Management Institute (PMI)**:

The PMI, as a global leader in project management, could benefit from adopting such a framework. By incorporating this approach, PMI can enhance project management practices specific to high-rise buildings. It would provide a structured methodology for addressing time-overrun risks and optimizing schedules.

ii. Government Support:

- **Regulation and Policy:** The government should develop policies that enforces and mandate the use of advanced PM tools in HRB projects. This entails regulations for change order management, correct project estimation and , design completeness.
- **Funding and Incentives:** Promote financial supports, grants, or subsidies to construction companies that adopt innovative management tools and practices. This can assist in offsetting high maintenance and implementation costs associated with these tools.
- **Training Programs:** Introduce government-funded training programs to educate construction professionals on the use of advanced project management tools. This is for continues improvement and ability to manage complex projects and reduce errors during use.

iii. Stakeholder Engagement:

- **Collaboration Platforms:** Create online platforms for stakeholders (including vendors, engineers, and architects) to share information, track progress, and address issues together.
- **Stakeholders' Meetings**: Hold regular meetings with stakeholders to discuss project progress, challenges, and solutions, ensuring everyone is aligned and working towards successful project completion.

a) **Adoption of Advanced Tools**:

- ✧ Change Orders Management: Encourage the use of tools like Builder trend and Procore to manage change orders efficiently and reduce delays.
- ✧ Incomplete Design: Promote the adoption of BIM (Building Information Modeling) combined with WBS (Work Breakdown Structure) to ensure comprehensive and complete designs.
- ✧ Accurate Estimation: Advocate for the use of tools like Project sight and Archdesk for more accurate project estimation.
- ✧ Material Cost Management: Support the implementation of Neural Network models in MATLAB to predict and manage material cost fluctuations.
- ✧ Labor Optimization: Encourage the use of SMARTBUILD to optimize labour allocation and address shortages.

b) **Risk Management and Quality Control**:

- ✧ Risk Assessment: Implement regular risk assessments and quality control measures to identify and mitigate potential issues at the early stage. This can be supported by government regulations and industry standards.
- ✧ Safety Protocols: Enforce strict safety protocols on construction sites to prevent accidents and ensure the well-being of workers.

c) **Weather Prediction and Planning**:

- ✧ Weather Forecasting Tools: Support the use of tools like Baron Radars for accurate weather forecasting to plan and adjust construction schedules accordingly.

d) **Resource Allocation and Management**:

- ✧ Effective Resource Management: Use tools like Runn to manage resources effectively, ensuring projects are completed on time, within budget, and to the required quality.
- ✧ Data Sharing and Collaboration: Encourage the use of web-based tools with file sharing, issue tracking, and task scheduling features to streamline project management and enhance collaboration among stakeholders.

5.3 CONCLUSION

The below conclusions can be drawn based on the findings regarding the elimination of delays and cost overruns in HRB construction in Lagos State:

There is critical interplay between performance and project management factors (cost, time, and scope) in HRB production. Effective management of cost, time, and scope is critical for successful project outcomes. The key challenges identified, including changes, design errors, underestimation, and resource issues, can lead to project failure (including project delays, cost overruns, and safety risks). Hence there is need for holistic reforms in HRB construction in Lagos State.

The comparative analysis of current and proposed project management tools in Lagos State reveals significant deficiencies in existing tools, hindering efficient elimination of delays and cost overruns in HRB construction. Hence the need to develop a framework for optimizing project management tools to mitigate delays, cost overruns, and risks in high-rise building (HRB) production in Lagos State.

The identified characteristics for effective project management tools for HRB construction, encompassing cost analysis, communication, estimation, and quality management, underscore the importance of integrated and holistic project management approaches. These characteristics are necessary for addressing prevalent industry challenges.

5.4 CONTRIBUTION TO KNOWLEDGE AND RECOMMENDATION FOR FURTHER STUDIES:

5.4.1 Contribution To Knowledge

This study contributes significantly to the body of knowledge on mitigating delays, cost overruns and risk in HRB construction in Lagos State. The study's findings and framework provide new insights and practical solutions to the industry's existing challenges. This research specifically contributes to knowledge in the following areas:

i. Interplay between project management factors and their influence with respect to performance: The study reveals the critical relationship between cost, time, and scope in the performance of HRB production, emphasizing the need for holistic management approaches.
ii. Identification of key problems: The research identifies major problems (change orders, incomplete designs, underestimation, and resource allocation issues) hindering HRB construction, providing a foundation for targeted reforms.
iii. Need for holistic reforms: The study underscores the necessity for comprehensive reforms in HRB construction in Lagos State, addressing systemic deficiencies and industry challenges.
iv. Optimization of project management tools: The developed framework offers a novel approach to optimizing project management tools, mitigating delays, cost overruns, and risks in HRB production.
v. Characteristics of effective project management tools: The research identifies essential characteristics (cost analysis, communication, estimation, and quality

management) for effective project management tools, informing industry best practices.

Furthermore, this study advances theoretical understanding of project management dynamics in HRB construction, impact of systemic deficiencies on project performance and role of integrated project management approaches in addressing HRB production challenges.

It also offers practical guidance for construction professionals, stakeholders, policy-makers and regulatory bodies in Lagos State.

5.4.2 Recommendations for Future Studies:

This Research provides information on future research directions such as:

i. Investigating the applicability of the developed framework in other contexts.
ii. Developing more sophisticated project management tools.
iii. Investigate the impact of technological innovations on HRB construction, and examine how these innovations can improve efficiency, reduce costs, and enhance overall project outcomes.

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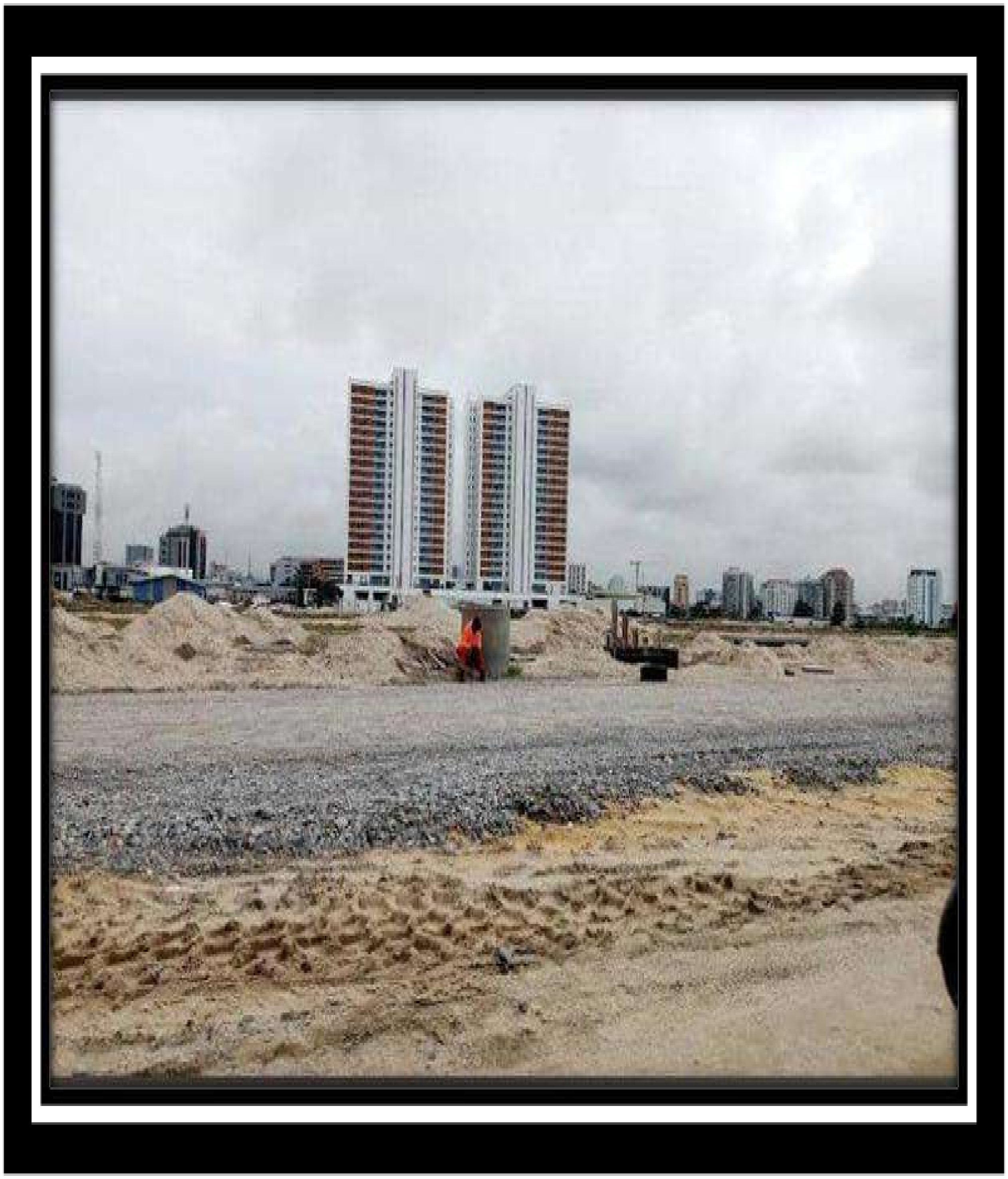
APPENDIXES

APPENDIX I

Eko Pearl (Source: Field Study, 2023)



KURAMO(2NOS TOWERS, 18FLOORS EACH OPPOSITE MANSARD)(Source: Field Study, 2023)

EDEN HEIGHT (Source: Field Study, 2023)

OKUTA RESIDENCE – 7, REEVES ROAD IKOYI-3D **(Source: Field Study, 2023)**

OKUTA RESIDENCE – 7, REEVES ROAD IKOYI-FINSHING WIP

OKUTA RESIDENCES FINISHES **(Source: Field Study, 2023)**

OKUTA RESIDENCES COMMON AREAS & FACILITIES (Source: Field Study, 2023)

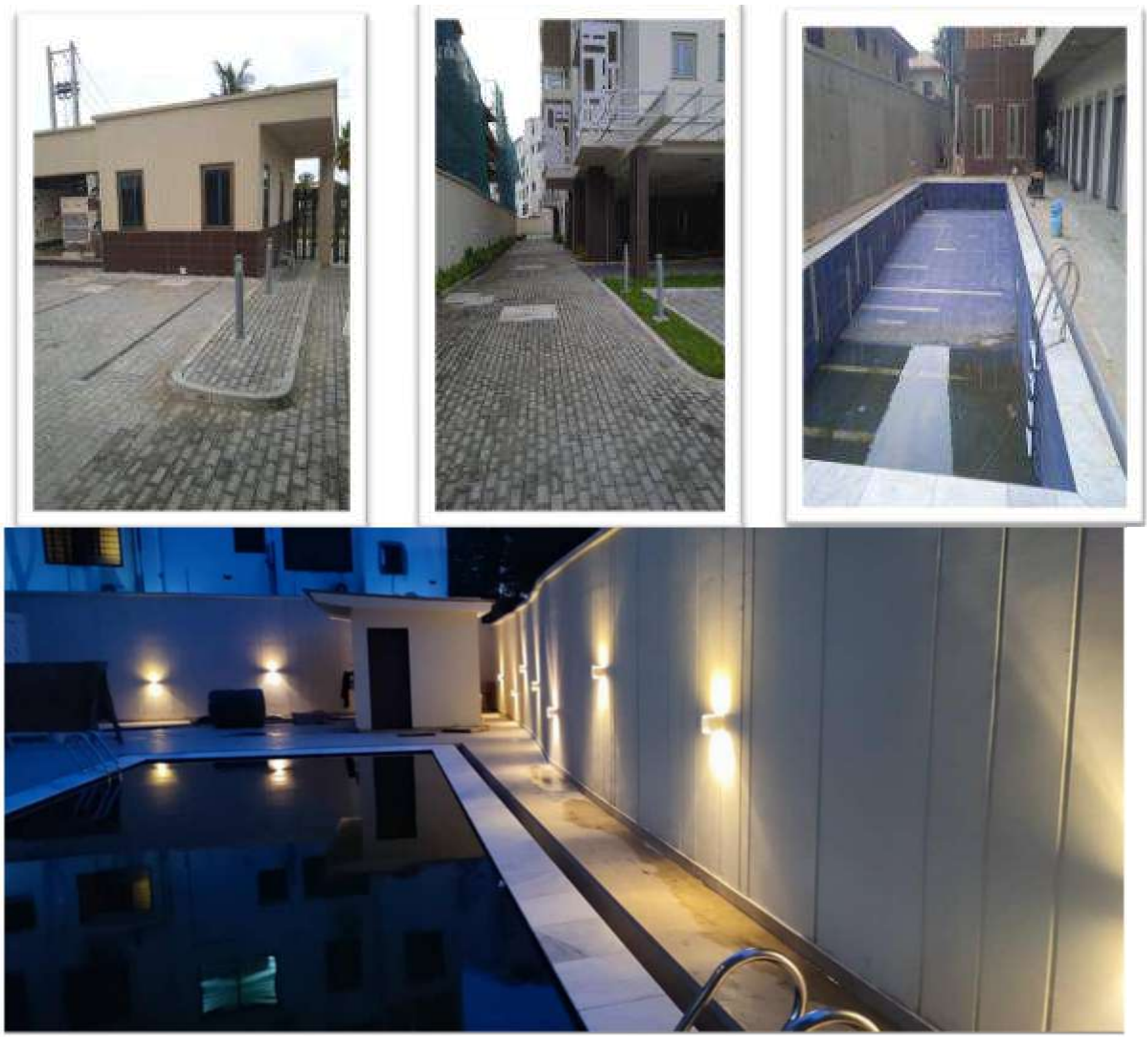
GEORGES COURT – COOPER ROAD, IKOYI-3D (Source: Field Study, 2023)

GEORGES COURT – COOPER ROAD, IKOYI-CARCASS WIP (Source: Field Study, 2023)

GEORGE'S COURT FINISHES (Source: Field Study, 2023)

GEORGE'S COURT FOUNDATION-01 (Source: Field Study, 2023)

GEORGE'S COURT FOUNDATION-02 (Source: Field Study, 2023)


GEORGE'S COURT COMMON AREAS & FACILITIES (Source: Field Study, 2023)

AZURI-PENINSULA EKO ATLANTIC CITY, LAGOS(3NOS TOWER;2NOS-32FLOORS & 1NO-29FLOORS)WHEN FINISHING WAS ONGOING (Source: Field Study, 2023)

(Source: Field Study, 2023)

Kingsway Tower, Ikoyi (Source: Field Study, 2023)

LETTER OF INTRODUCTION

Dear Respondent,

My name is Amanze Ikechukwu Uchenna. I am a PhD student at Imo State University, Owerri, Imo State. I am carrying out a study on my thesis topic: DEVELOPING A FRAMEWORK FOR USE OF PROJECT MANAGEMENT TOOLS ON HIGHRISE BUILDING PRODUCTION IN LAGOS STATE, NIGERIA. [A CASE STUDY OF IKOYI AND VICTORIA ISLAND, LAGOS STATE] as a requirement for my doctorate degree by the University.

Kindly fill out the questionnaire as honestly and objectively as possible. All information supplied will be treated with confidentiality and used only for academic purposes.

Thank you for your cooperation.

Sincerely yours,

Amanze Ikechukwu Uchenna, Ph.D*(CTM-IMSU*), R. Engr (Coren), *MBA (Accounting-UNILAG), MSc (Mathematics-LASU), MSc (CTM-IMSU),* MNSE*, PMP®, CFPM, CPM, CFM*

APPENDIX II

THE QUESTIONNAIRE

SECTION A

Characteristics of respondents used for this study

Please indicate Appropriately

Gender: Male ☐ Female ☐

Academic Qualification: PhD ☐ M.sc ☐ BSc/HND ☐ Diploma ☐ Others ☐

Position: Architect ☐ QSV ☐ PM ☐ Engineer ☐ Consultant ☐

Contractor Supervisor ☐ Builders ☐ Land Surveyor ☐

Years of Experience: 1-10 ☐ 11-15 ☐ 16-20 ☐ Above 20 ☐

Marital Status: Single ☐ Married ☐

SECTION B

Please indicate appropriately what you think are the characteristics of project management tools for high-rise buildings production in Lagos State.

	The following are the characteristics of project management tools for high-rise buildings production in Lagos State	SA 5	A 4	NS 3	D 2	SD 1
1.	Time tracking.					
2.	Task scheduling					
3.	Resource management					
4.	Collaboration					
5.	Estimating					
6.	Risk assessment					
7.	Change management					
8.	Project analysis and report					
9.	Document management					
10.	Communication tool					
11.	Process development					
12.	Portfolio management					
13.	Access control					
14.	Quality management					
15.	Web based					
16.	Issue tracking					
17.	Project planning					
18.	File sharing					
19.	Ease of use					
20.	Cost analysis					

Please indicate appropriately what you think is the performance of different project management tools for HRB production in Lagos State

	How is the performance of the following management tools for HRB production in Lagos State,	HE 5	E 4	SE 3	LS 2	NE 1
1.	Critical path method					
2.	Gantt chart					
3.	Network plan					
4.	Earned Value Management					
5.	Project Evaluation and Review Techniques					
6.	Work breakdown structure					
7.	Milestone chart					
8.	Business case					
9.	Primavera					
10.	MS-Project					
11.	Gantt Project					
12.	Redmine					
13.	Basecamp					
14.	Dot project					
15.	Assembla					
16.	Artemis view					
17.	Open project					
18.	Open workbench					
19.	Liquid Planner					
20.	BIM					

Please indicate appropriately what you think are the deficiencies of the project management tools for high-rise buildings production in Lagos State.

	The following are the deficiencies of the project management tools for high-rise buildings production in Lagos State	SA 5	A 4	NS 3	D 2	SD 1
1.	Less tracking of projects.					
2.	Impossibility in managing complex projects					
3.	Lack of logical representation of projects					
4.	Inability to represent valuable information					
5.	Non-prediction of project uncertainty					
6.	Inability to handle crashing tasks					
7.	High maintenance and implementation cost					
8.	Hindrance in data sharing					
9.	Complex of use					
10.	High rate of mistakes during use					
11.	Waste time					
12.	Needs supportive tools					
13.	Not good for high-rise buildings					

Please indicate appropriately what you think are the construction technology tools that can help eliminate challenges in HRB production in Lagos state.

	The following are the construction technology tools that can help eliminate challenges in HRB production in Lagos state	HE 5	E 4	SE 3	LS 2	NE 1
1.	BIM + GIS					
2.	BIM + digital programming					
3.	BIM + past data of completed projects					
4.	BIM + Radio Frequency Identification Device (RFID)					
5.	BIM environment + cost estimation software					
6.	SMARTBUILD					
7.	Archdest					
8.	BIM + query language					
9.	Neutral Network in MATLAB					
10.	BIM + cost-based progress curves					
11.	Project sight					
12.	BIM + Earned Value Analysis (EVA)					
13.	BIM + 4-Dimensional Augment Reality (AR)					
14.	Runn)					
15.	BIM + Critical Path Method (CPM)					
16.	BIM + 3D imaging technologies					
17.	4D BIM model					
18.	Builder trend,					
19.	Procore					

Appendix III
IBM SPSS Output Regarding Research Question One and Hypothesis One
Case Processing Summary

Figure i

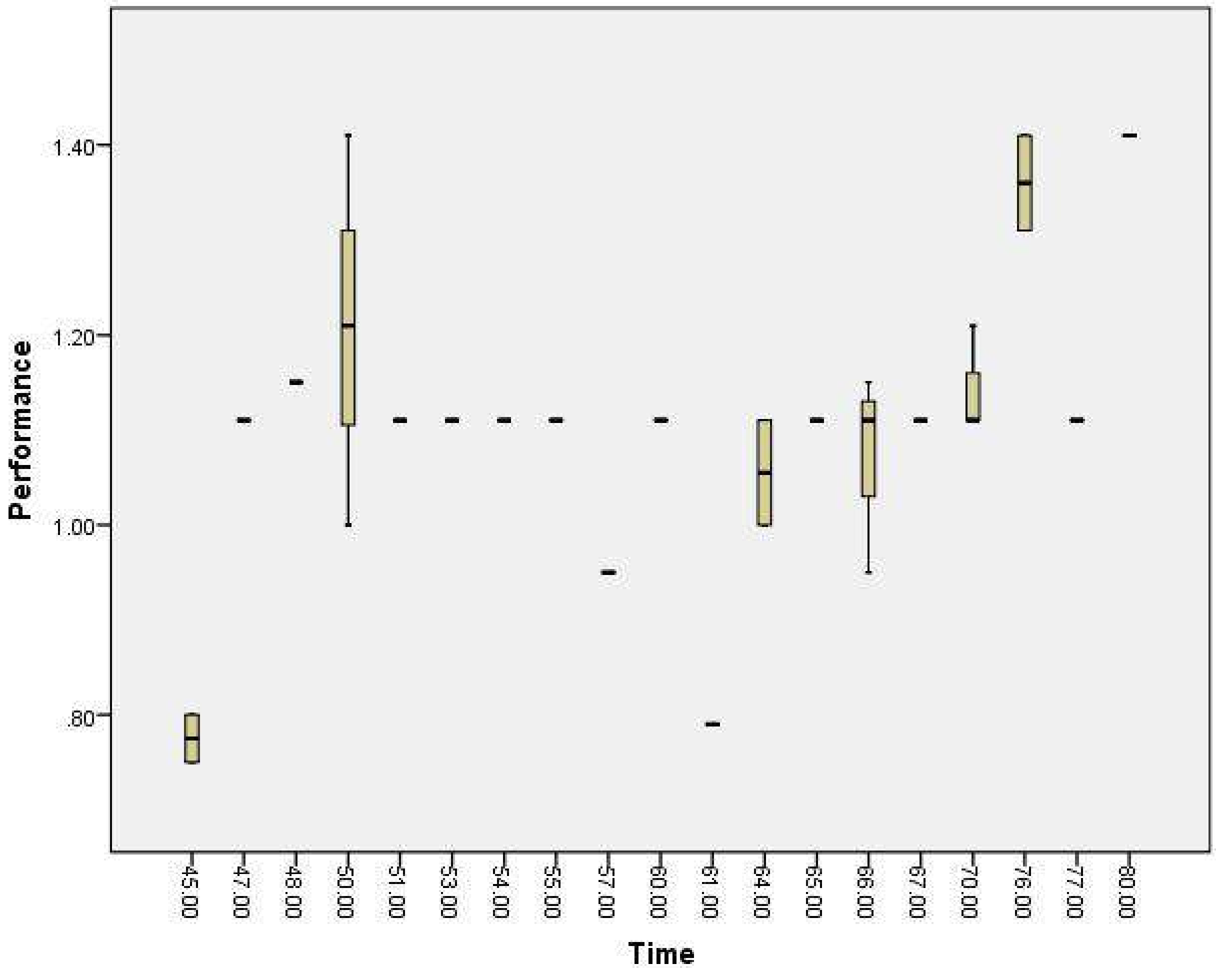
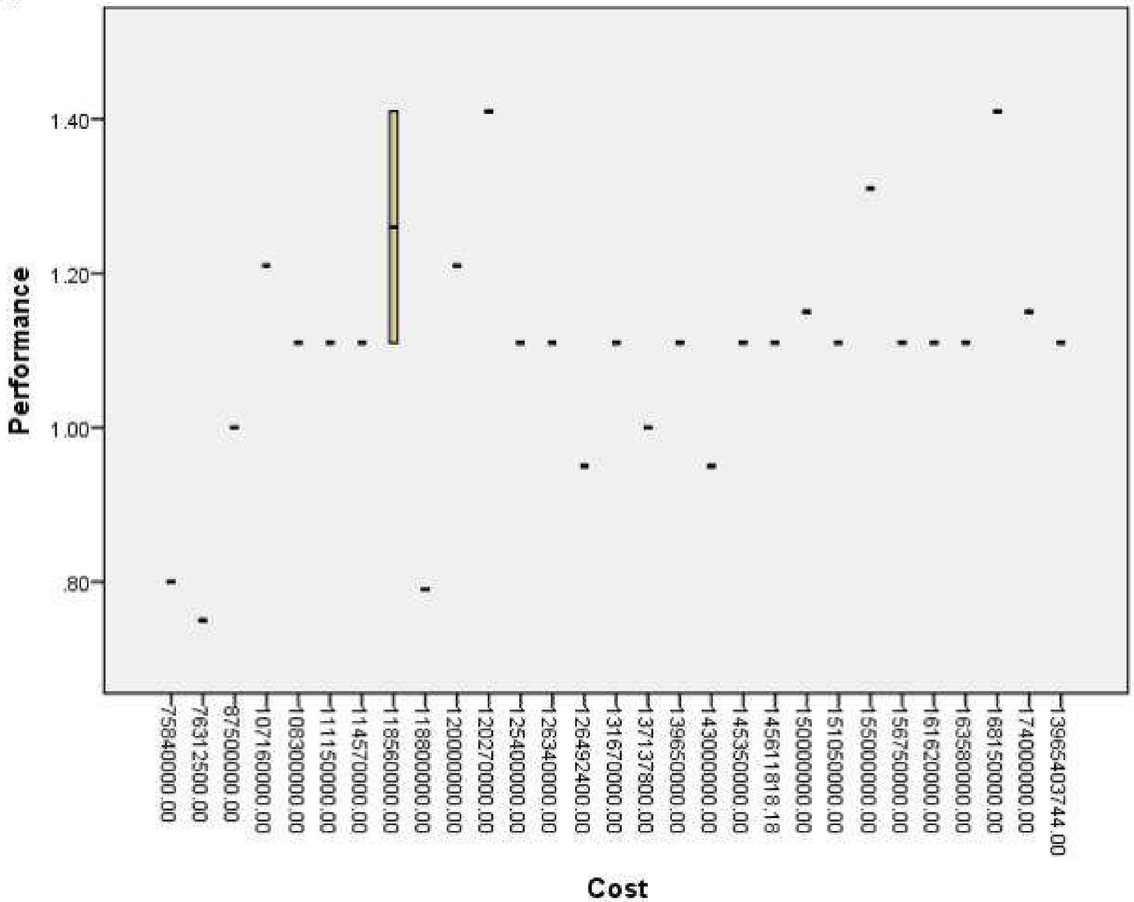


Figure ii



Performance
1.40
1.20
1.00
.80
75840000.00
76312500.00
87500000.00
107160000.00
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114570000.00
118560000.00
118800000.00
120000000.00
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1396540374 4.00
Cost

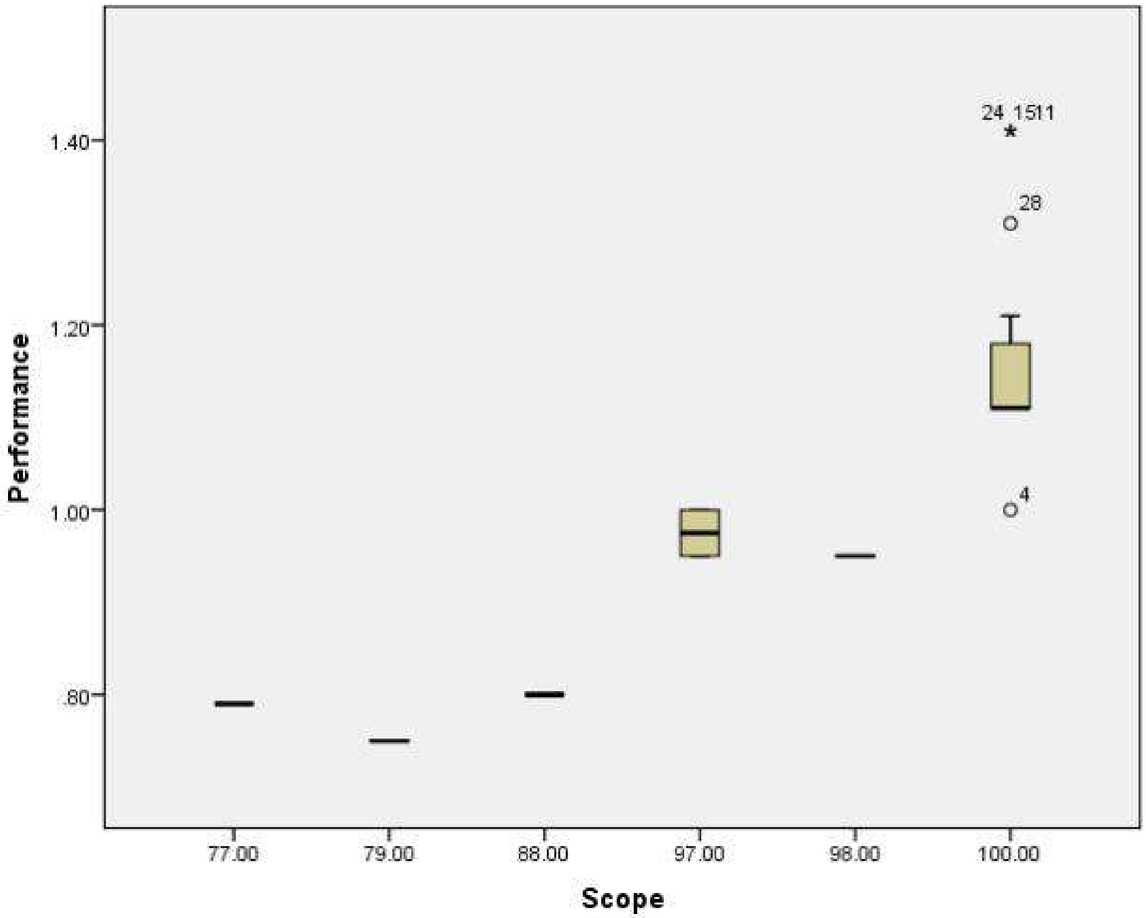

24 1511
28
4
1.40
1.20
1.00
.80
Performance
77.00
79.00
88.00
97.00
98.00
100.00
Scope

Table i

Tests of Normality

	Time	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Performance	45.00	.260	2	.			
	50.00	.177	3	.	1.000	3	.973
	64.00	.260	2	.			
	66.00	.382	4	.	.801	4	.103
	70.00	.385	3	.	.750	3	.000
	76.00	.260	2	.			

a. Lilliefors Significance Correction

Table ii

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	Df	Sig.
Cost	.532	30	.000	.187	30	0.34

a. Lilliefors Significance Correction

Table iii

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	Df	Sig.
Time	.123	30	.200*	.951	30	.180

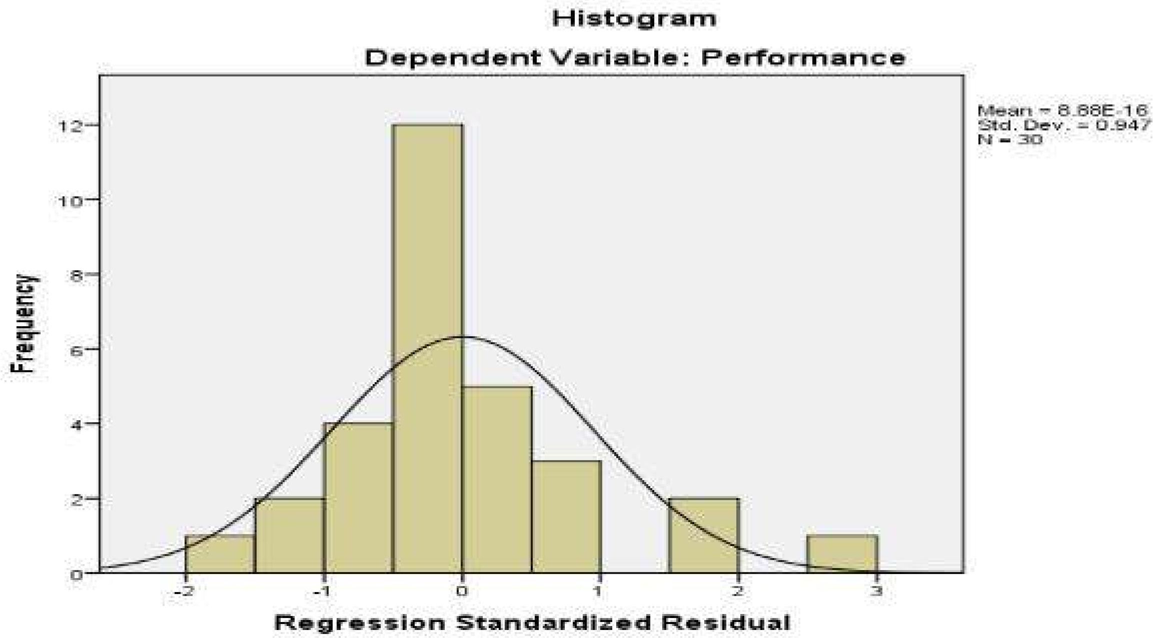
a. Lilliefors Significance Correction

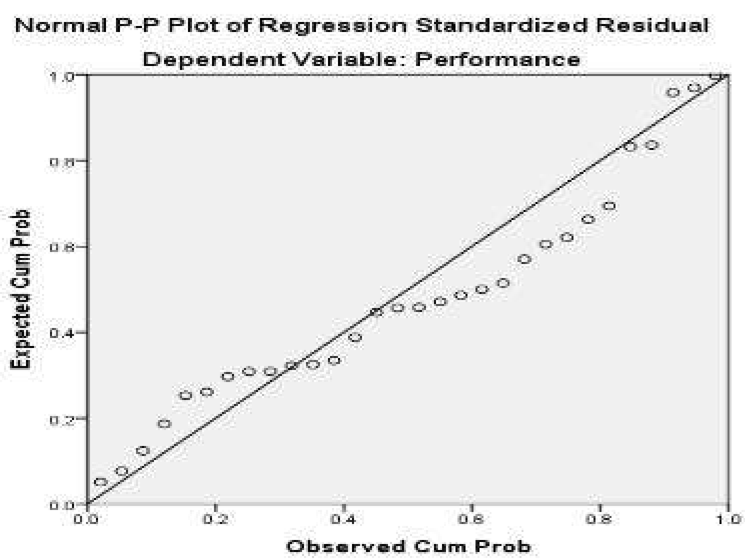
*. This is a lower bound of the true significance.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	Df	Sig.
Scope	.442	30	.000	.418	30	0.64

a. Lilliefors Significance Correction





Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	Cost[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Performance

Table B11

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.0.52	0.2704	0.323	.16211

a. Predictors: (Constant), Cost

Table B12

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.3214.64	1	.212.33	.9.67	.0.0023
	Residual	.736	28	.026		
	Total	.736	29			

a. Predictors: (Constant), Cost

b. Dependent Variable: Performance

Table B13

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.105	.030		36.305	.000
	Cost	.2.015	.000	.010	.055	0.000

a. Dependent Variable: Performance

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Time[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Performance

Table B21

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.441[a]	.194	.166	.14551

a. Predictors: (Constant), Time

Table B22

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.143	1	.143	6.758	.015[a]
	Residual	.593	28	.021		
	Total	.736	29			

a. Predictors: (Constant), Time

b. Dependent Variable: Performance

Tanle B23

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.687	.163		4.208	.000
	Time	.007	.003	.441	2.600	.015

a. Dependent Variable: Performance

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Scope[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Performance

Table B31

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.717[a]	.514	.497	.11299

a. Predictors: (Constant), Scope

Table B32

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.379	1	.379	29.650	.000[a]
	Residual	.357	28	.013		
	Total	.736	29			

a. Predictors: (Constant), Scope

b. Dependent Variable: Performance

Table B33

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.800	.350		-2.282	.030
	Scope	.019	.004	.717	5.445	.000

a. Dependent Variable: Performance

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Scope, Cost, Time	.	Enter

a. All requested variables entered.

b. Dependent Variable: Performance

Table B41

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.756[a]	.571	.522	.11013

a. Predictors: (Constant), Scope, Cost, Time

Table B42

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.421	3	.140	11.558	.000[a]
	Residual	.315	26	.012		
	Total	.736	29			

a. Predictors: (Constant), Scope, Cost, Time

b. Dependent Variable: Performance

Table B43

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.839	.343		-2.450	.021
	Cost	.000	.000	-.081	-.621	0.023
	Time	.004	.002	.251	1.833	.0024
	Scope	.017	.004	.644	4.754	.000

a. Dependent Variable: Performance

Appendix IV
IBM SPSS Output Regarding Research Question Two and Hypothesis Two

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of CVPMT is the same across categories of Groups.	Independent-Samples Kruskal-Wallis Test	<.001	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Independent-Samples Kruskal-Wallis Test Summary

Total N	4160
Test Statistic	228.495[a]
Degree Of Freedom	19
Asymptotic Sig.(2-sided test)	<.001

a. The test statistic is adjusted for ties.

Pairwise Comparisons of Groups

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Quality management-Ease of use	-446.428	113.685	-3.927	<.001	.016
Quality management-Process development	484.990	113.685	4.266	<.001	.004
Quality management-Access control	544.938	113.685	4.793	<.001	.000
Quality management-Change management	567.041	113.685	4.988	<.001	.000
Quality management-Document management	610.716	113.685	5.372	<.001	.000
Quality management-Project planning	-781.344	113.685	-6.873	<.001	.000
Quality management-Collaboration	850.231	113.685	7.479	<.001	.000
Quality management-Portfolio management	869.514	113.685	7.648	<.001	.000
Quality management-Task scheduling	920.144	113.685	8.094	<.001	.000
Quality management-Issue tracking	-925.512	113.685	-8.141	<.001	.000
Quality management-Web based	-942.846	113.685	-8.294	<.001	.000
Quality management-File sharing	-949.024	113.685	-8.348	<.001	.000
Quality management-Resource management	1002.207	113.685	8.816	<.001	.000
Quality management-Time tracking	1008.565	113.685	8.872	<.001	.000
Quality management-Project	1010.291	113.685	8.887	<.001	.000

analysis and report					
Quality management-Estimating	1012.538	113.685	8.907	<.001	.000
Quality management-Risk assessment	1013.668	113.685	8.916	<.001	.000
Quality management-Communication tool	1046.719	113.685	9.207	<.001	.000
Quality management-Cost analysis	-1111.168	113.685	-9.774	<.001	.000
Ease of use-Process development	38.563	113.685	.339	.734	1.000
Ease of use-Access control	98.510	113.685	.867	.386	1.000
Ease of use-Change management	120.613	113.685	1.061	.289	1.000
Ease of use-Document management	164.288	113.685	1.445	.148	1.000
Ease of use-Project planning	334.916	113.685	2.946	.003	.612
Ease of use-Collaboration	403.803	113.685	3.552	<.001	.073
Ease of use-Portfolio management	423.087	113.685	3.722	<.001	.038
Ease of use-Task scheduling	473.716	113.685	4.167	<.001	.006
Ease of use-Issue tracking	479.084	113.685	4.214	<.001	.005
Ease of use-Web based	496.418	113.685	4.367	<.001	.002
Ease of use-File sharing	502.596	113.685	4.421	<.001	.002
Ease of use-Resource management	555.779	113.685	4.889	<.001	.000
Ease of use-Time tracking	562.137	113.685	4.945	<.001	.000
Ease of use-Project analysis and report	563.863	113.685	4.960	<.001	.000
Ease of use-Estimating	566.111	113.685	4.980	<.001	.000
Ease of use-Risk assessment	567.240	113.685	4.990	<.001	.000
Ease of use-Communication tool	600.291	113.685	5.280	<.001	.000
Ease of use-Cost analysis	-664.740	113.685	-5.847	<.001	.000
Process development-Access control	-59.947	113.685	-.527	.598	1.000
Process development-Change management	82.050	113.685	.722	.470	1.000
Process development-Document management	125.726	113.685	1.106	.269	1.000
Process development-Project planning	-296.353	113.685	-2.607	.009	1.000
Process development-Collaboration	365.240	113.685	3.213	.001	.250
Process development-Portfolio management	-384.524	113.685	-3.382	<.001	.137
Process development-Task scheduling	435.154	113.685	3.828	<.001	.025
Process development-Issue tracking	-440.522	113.685	-3.875	<.001	.020
Process development-Web based	-457.856	113.685	-4.027	<.001	.011
Process development-File	-464.034	113.685	-4.082	<.001	.008

sharing					
Process development-Resource management	517.216	113.685	4.550	<.001	.001
Process development-Time tracking	523.575	113.685	4.606	<.001	.001
Process development-Project analysis and report	525.300	113.685	4.621	<.001	.001
Process development-Estimating	527.548	113.685	4.640	<.001	.001
Process development-Risk assessment	528.678	113.685	4.650	<.001	.001
Process development-Communication tool	561.728	113.685	4.941	<.001	.000
Process development-Cost analysis	-626.178	113.685	-5.508	<.001	.000
Access control-Change management	22.103	113.685	.194	.846	1.000
Access control-Document management	65.779	113.685	.579	.563	1.000
Access control-Project planning	-236.406	113.685	-2.079	.038	1.000
Access control-Collaboration	305.293	113.685	2.685	.007	1.000
Access control-Portfolio management	324.577	113.685	2.855	.004	.818
Access control-Task scheduling	375.207	113.685	3.300	<.001	.183
Access control-Issue tracking	-380.575	113.685	-3.348	<.001	.155
Access control-Web based	-397.909	113.685	-3.500	<.001	.088
Access control-File sharing	-404.087	113.685	-3.554	<.001	.072
Access control-Resource management	457.269	113.685	4.022	<.001	.011
Access control-Time tracking	463.627	113.685	4.078	<.001	.009
Access control-Project analysis and report	465.353	113.685	4.093	<.001	.008
Access control-Estimating	467.601	113.685	4.113	<.001	.007
Access control-Risk assessment	468.731	113.685	4.123	<.001	.007
Access control-Communication tool	501.781	113.685	4.414	<.001	.002
Access control-Cost analysis	-566.231	113.685	-4.981	<.001	.000
Change management-Document management	-43.675	113.685	-.384	.701	1.000
Change management-Project planning	-214.303	113.685	-1.885	.059	1.000
Change management-Collaboration	283.190	113.685	2.491	.013	1.000
Change management-Portfolio management	-302.474	113.685	-2.661	.008	1.000
Change management-Task scheduling	353.103	113.685	3.106	.002	.360
Change management-Issue tracking	-358.471	113.685	-3.153	.002	.307
Change management-Web based	-375.805	113.685	-3.306	<.001	.180

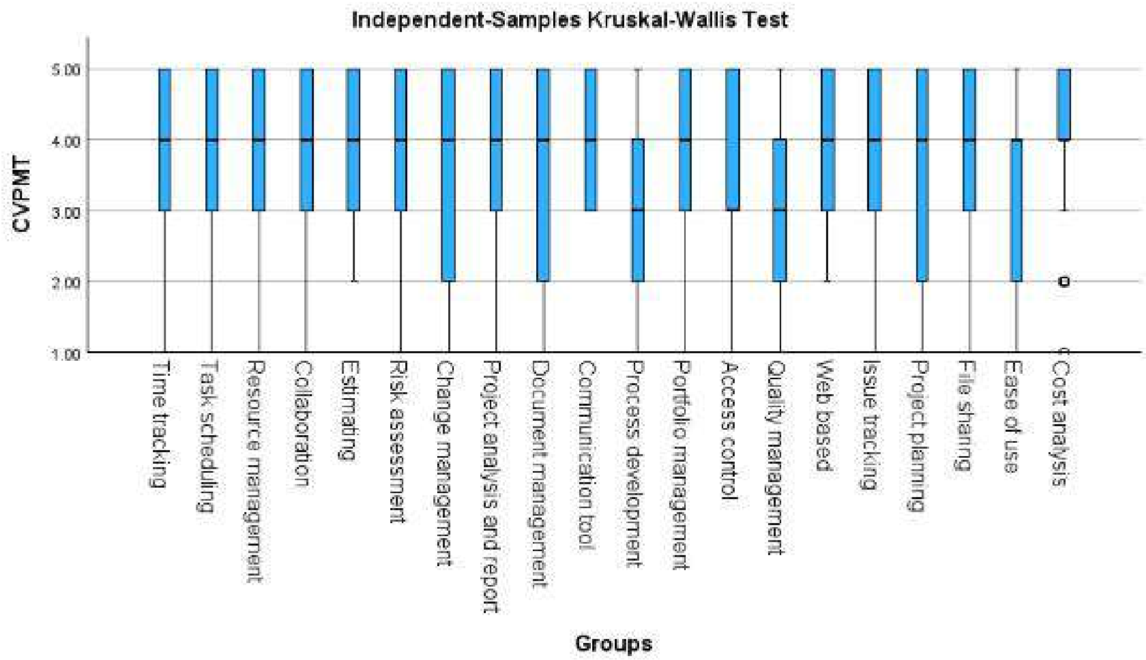
Change management-File sharing	-381.983	113.685	-3.360	<.001	.148
Change management-Resource management	435.166	113.685	3.828	<.001	.025
Change management-Time tracking	441.524	113.685	3.884	<.001	.020
Change management-Project analysis and report	-443.250	113.685	-3.899	<.001	.018
Change management-Estimating	445.498	113.685	3.919	<.001	.017
Change management-Risk assessment	446.627	113.685	3.929	<.001	.016
Change management-Communication tool	-479.678	113.685	-4.219	<.001	.005
Change management-Cost analysis	-544.127	113.685	-4.786	<.001	.000
Document management-Project planning	-170.627	113.685	-1.501	.133	1.000
Document management-Collaboration	239.514	113.685	2.107	.035	1.000
Document management-Portfolio management	-258.798	113.685	-2.276	.023	1.000
Document management-Task scheduling	309.428	113.685	2.722	.006	1.000
Document management-Issue tracking	-314.796	113.685	-2.769	.006	1.000
Document management-Web based	-332.130	113.685	-2.922	.003	.662
Document management-File sharing	-338.308	113.685	-2.976	.003	.555
Document management-Resource management	391.490	113.685	3.444	<.001	.109
Document management-Time tracking	397.849	113.685	3.500	<.001	.089
Document management-Project analysis and report	399.575	113.685	3.515	<.001	.084
Document management-Estimating	401.822	113.685	3.535	<.001	.078
Document management-Risk assessment	402.952	113.685	3.544	<.001	.075
Document management-Communication tool	-436.002	113.685	-3.835	<.001	.024
Document management-Cost analysis	-500.452	113.685	-4.402	<.001	.002
Project planning-Collaboration	68.887	113.685	.606	.545	1.000
Project planning-Portfolio management	88.171	113.685	.776	.438	1.000
Project planning-Task scheduling	138.800	113.685	1.221	.222	1.000
Project planning-Issue tracking	144.168	113.685	1.268	.205	1.000
Project planning-Web based	161.502	113.685	1.421	.155	1.000
Project planning-File sharing	-167.680	113.685	-1.475	.140	1.000

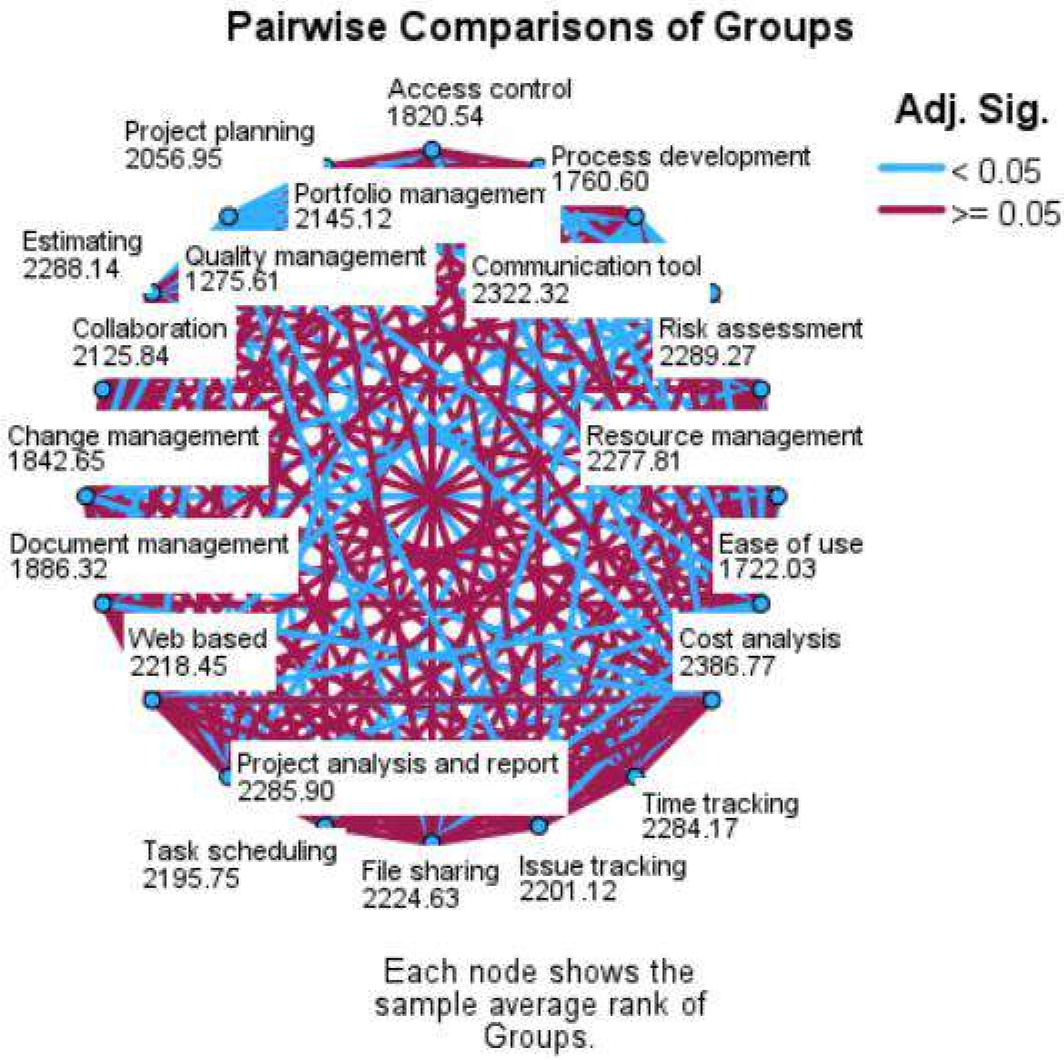
Project planning-Resource management	220.863	113.685	1.943	.052	1.000
Project planning-Time tracking	227.221	113.685	1.999	.046	1.000
Project planning-Project analysis and report	228.947	113.685	2.014	.044	1.000
Project planning-Estimating	231.195	113.685	2.034	.042	1.000
Project planning-Risk assessment	232.325	113.685	2.044	.041	1.000
Project planning-Communication tool	265.375	113.685	2.334	.020	1.000
Project planning-Cost analysis	-329.825	113.685	-2.901	.004	.706
Collaboration-Portfolio management	-19.284	113.685	-.170	.865	1.000
Collaboration-Task scheduling	69.913	113.685	.615	.539	1.000
Collaboration-Issue tracking	-75.281	113.685	-.662	.508	1.000
Collaboration-Web based	-92.615	113.685	-.815	.415	1.000
Collaboration-File sharing	-98.793	113.685	-.869	.385	1.000
Collaboration-Resource management	151.976	113.685	1.337	.181	1.000
Collaboration-Time tracking	158.334	113.685	1.393	.164	1.000
Collaboration-Project analysis and report	-160.060	113.685	-1.408	.159	1.000
Collaboration-Estimating	-162.308	113.685	-1.428	.153	1.000
Collaboration-Risk assessment	-163.438	113.685	-1.438	.151	1.000
Collaboration-Communication tool	-196.488	113.685	-1.728	.084	1.000
Collaboration-Cost analysis	-260.938	113.685	-2.295	.022	1.000
Portfolio management-Task scheduling	50.630	113.685	.445	.656	1.000
Portfolio management-Issue tracking	-55.998	113.685	-.493	.622	1.000
Portfolio management-Web based	-73.332	113.685	-.645	.519	1.000
Portfolio management-File sharing	-79.510	113.685	-.699	.484	1.000
Portfolio management-Resource management	132.692	113.685	1.167	.243	1.000
Portfolio management-Time tracking	139.050	113.685	1.223	.221	1.000
Portfolio management-Project analysis and report	140.776	113.685	1.238	.216	1.000
Portfolio management-Estimating	143.024	113.685	1.258	.208	1.000
Portfolio management-Risk assessment	144.154	113.685	1.268	.205	1.000
Portfolio management-Communication tool	177.204	113.685	1.559	.119	1.000
Portfolio management-Cost analysis	-241.654	113.685	-2.126	.034	1.000
Task scheduling-Issue tracking	-5.368	113.685	-.047	.962	1.000
Task scheduling-Web based	-22.702	113.685	-.200	.842	1.000
Task scheduling-File sharing	-28.880	113.685	-.254	.799	1.000

Task scheduling-Resource management	-82.063	113.685	-.722	.470	1.000
Task scheduling-Time tracking	88.421	113.685	.778	.437	1.000
Task scheduling-Project analysis and report	-90.147	113.685	-.793	.428	1.000
Task scheduling-Estimating	-92.394	113.685	-.813	.416	1.000
Task scheduling-Risk assessment	-93.524	113.685	-.823	.411	1.000
Task scheduling-Communication tool	-126.575	113.685	-1.113	.266	1.000
Task scheduling-Cost analysis	-191.024	113.685	-1.680	.093	1.000
Issue tracking-Web based	17.334	113.685	.152	.879	1.000
Issue tracking-File sharing	-23.512	113.685	-.207	.836	1.000
Issue tracking-Resource management	76.695	113.685	.675	.500	1.000
Issue tracking-Time tracking	83.053	113.685	.731	.465	1.000
Issue tracking-Project analysis and report	84.779	113.685	.746	.456	1.000
Issue tracking-Estimating	87.026	113.685	.766	.444	1.000
Issue tracking-Risk assessment	88.156	113.685	.775	.438	1.000
Issue tracking-Communication tool	121.207	113.685	1.066	.286	1.000
Issue tracking-Cost analysis	-185.656	113.685	-1.633	.102	1.000
Web based-File sharing	-6.178	113.685	-.054	.957	1.000
Web based-Resource management	59.361	113.685	.522	.602	1.000
Web based-Time tracking	65.719	113.685	.578	.563	1.000
Web based-Project analysis and report	67.445	113.685	.593	.553	1.000
Web based-Estimating	69.692	113.685	.613	.540	1.000
Web based-Risk assessment	70.822	113.685	.623	.533	1.000
Web based-Communication tool	103.873	113.685	.914	.361	1.000
Web based-Cost analysis	-168.322	113.685	-1.481	.139	1.000
File sharing-Resource management	53.183	113.685	.468	.640	1.000
File sharing-Time tracking	59.541	113.685	.524	.600	1.000
File sharing-Project analysis and report	61.267	113.685	.539	.590	1.000
File sharing-Estimating	63.514	113.685	.559	.576	1.000
File sharing-Risk assessment	64.644	113.685	.569	.570	1.000
File sharing-Communication tool	97.695	113.685	.859	.390	1.000
File sharing-Cost analysis	-162.144	113.685	-1.426	.154	1.000
Resource management-Time tracking	6.358	113.685	.056	.955	1.000
Resource management-Project analysis and report	-8.084	113.685	-.071	.943	1.000
Resource management-Estimating	-10.332	113.685	-.091	.928	1.000
Resource management-Risk assessment	-11.462	113.685	-.101	.920	1.000
Resource management-	-44.512	113.685	-.392	.695	1.000

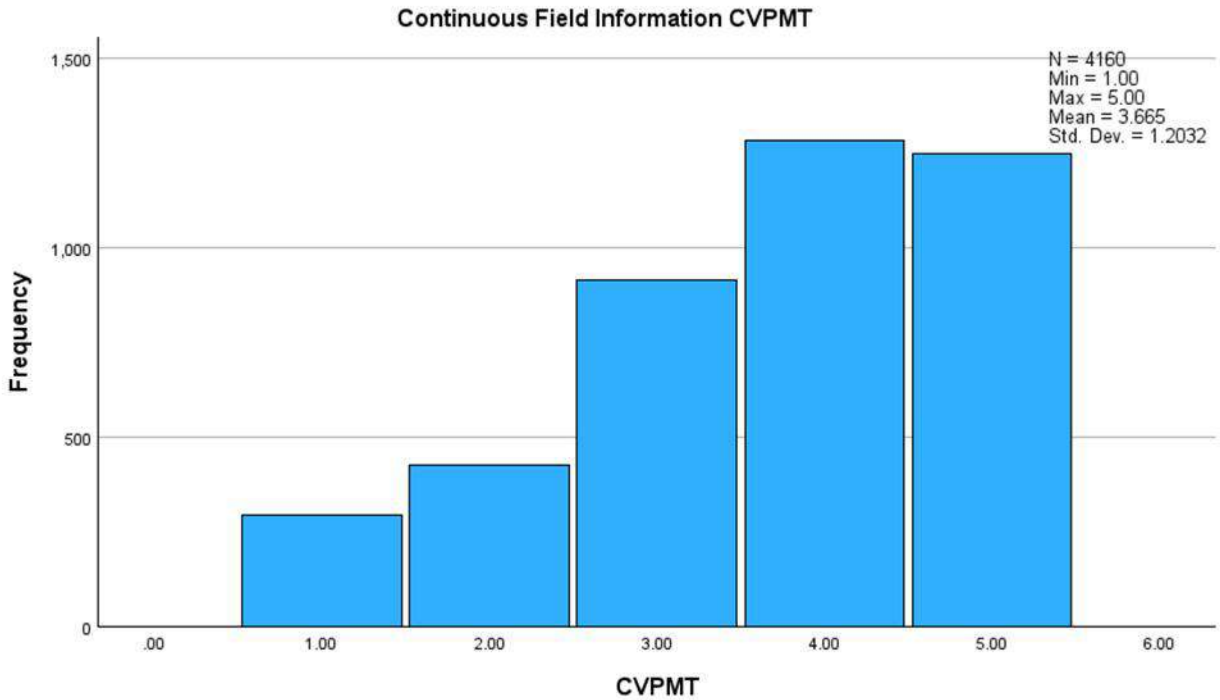
Communication tool					
Resource management-Cost analysis	-108.962	113.685	-.958	.338	1.000
Time tracking-Project analysis and report	-1.726	113.685	-.015	.988	1.000
Time tracking-Estimating	-3.974	113.685	-.035	.972	1.000
Time tracking-Risk assessment	-5.103	113.685	-.045	.964	1.000
Time tracking-Communication tool	-38.154	113.685	-.336	.737	1.000
Time tracking-Cost analysis	-102.603	113.685	-.903	.367	1.000
Project analysis and report-Estimating	2.248	113.685	.020	.984	1.000
Project analysis and report-Risk assessment	3.377	113.685	.030	.976	1.000
Project analysis and report-Communication tool	-36.428	113.685	-.320	.749	1.000
Project analysis and report-Cost analysis	-100.877	113.685	-.887	.375	1.000
Estimating -Risk assessment	-1.130	113.685	-.010	.992	1.000
Estimating -Communication tool	-34.180	113.685	-.301	.764	1.000
Estimating -Cost analysis	-98.630	113.685	-.868	.386	1.000
Risk assessment-Communication tool	-33.050	113.685	-.291	.771	1.000
Risk assessment-Cost analysis	-97.500	113.685	-.858	.391	1.000
Communication tool-Cost analysis	-64.450	113.685	-.567	.571	1.000

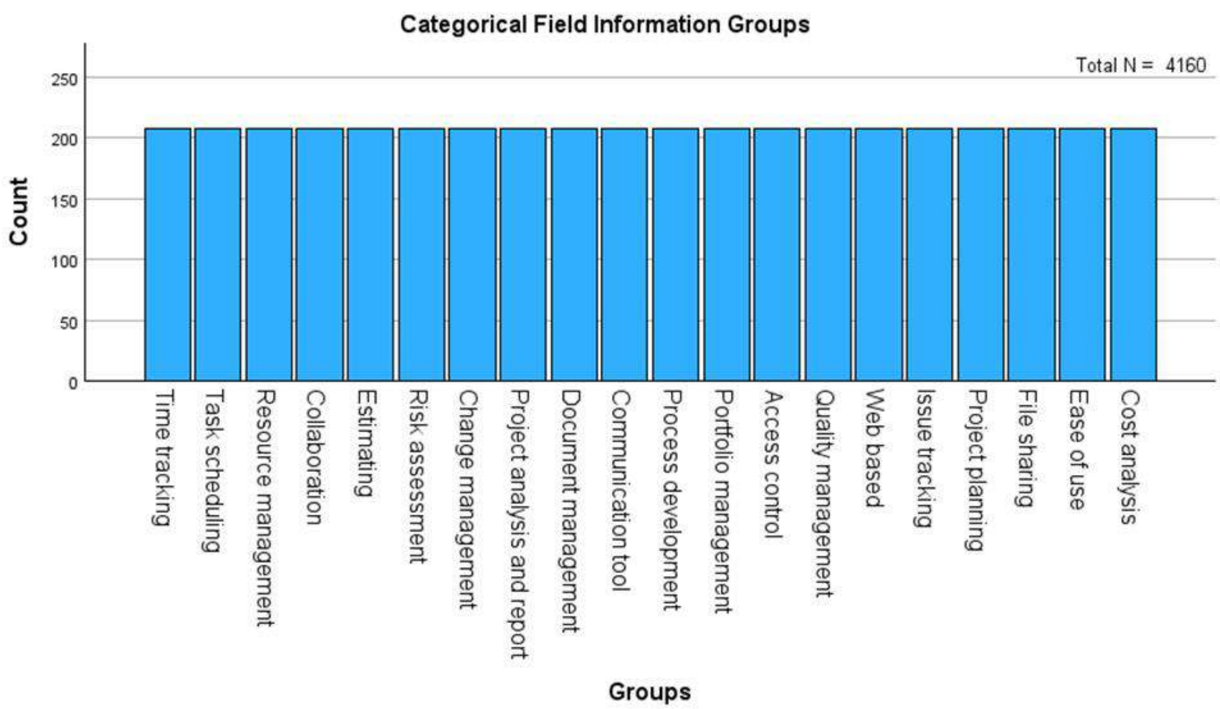
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.


Independent-Samples Kruskal-Wallis Test
CVPMT
5.00
4.00
3.00
2.00
1.00
Time tracking
Task scheduling
Resource management
Collaboration
Estimating
Risk assessment
Change management
Project analysis and report
Document management
Communication tool
Process development
Portfolio management
Access control
Quality management
Web based
Issue tracking
Project planning
File sharing
Ease of use
Cost analysis
Groups



Pairwise Comparisons of Groups
Adj. Sig.
< 0.05
>= 0.05
Access control
1820.54
Project planning
2056.95
Process development
1760.60
Portfolio managemen
2145.12
Estimating
2288.14
Quality management
1275.61
Communication tool
2322.32
Collaboration
2125.84
Risk assessment
2289.27
Change management
1842.65
Resource management
2277.81
Document management
1886.32
Ease of use
1722.03
Web based
2218.45
Cost analysis
2386.77
Project analysis and report
2285.90
Time tracking
2284.17
Task scheduling
2195.75
File sharing
2224.63
Issue tracking
2201.12
Each node shows the sample average rank of Groups.


Continuous Field Information CVPMT
N = 4160
Min = 1.00
Max = 5.00
Mean = 3.665
Std. Dev. = 1.2032
Frequency
1,500
1,000
500
0
.00
1.00
2.00
3.00
4.00
5.00
6.00
CVPMT


Categorical Field Information Groups
Total N = 4160
Count
250
200
150
100
50
0
Time tracking
Task scheduling
Resource management
Collaboration
Estimating
Risk assessment
Change management
Project analysis and report
Document management
Communication tool
Process development
Portfolio management
Access control
Quality management
Web based
Issue tracking
Project planning
File sharing
Ease of use
Cost analysis
Groups

Appendix V
IBM SPSS Output Regarding Research Question Three and Hypothesis Three

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
RII	39	.6803	.08752	.48	.86
Management Tools	39	1.4872	.50637	1.00	2.00

Ranks

	Management Tools	N	Mean Rank	Sum of Ranks
RII	PMTHRB	20	16.20	324.00
	OPMT	19	24.00	456.00
	Total	39		

cc

	RII
Mann-Whitney U	114.000
Wilcoxon W	324.000
Z	-2.141
Asymp. Sig. (2-tailed)	.032
Exact Sig. [2*(1-tailed Sig.)]	.033[b]

a. Grouping Variable: Management Tools
b. Not corrected for ties.

Appendix VI
IBM SPSS Output Regarding Research Question Four and Hypothesis Four

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of DPMTHRB is the same across categories of Groups4.	Independent-Samples Kruskal-Wallis Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Independent-Samples Kruskal-Wallis Test Summary

Total N	2704
Test Statistic	221.699[a]
Degree Of Freedom	12
Asymptotic Sig.(2-sided test)	<.001

a. The test statistic is adjusted for ties.

Pairwise Comparisons of Groups4

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Lack of logical representation of projects-Hindrance in data sharing	-151.055	74.143	-2.037	.042	1.000
Lack of logical representation of projects-Waste time	-219.067	74.143	-2.955	.003	.244
Lack of logical representation of projects-High rate of mistakes during use	-258.269	74.143	-3.483	<.001	.039
Lack of logical representation of projects-Inability to represent valuable information	-453.875	74.143	-6.122	<.001	.000
Lack of logical representation of projects-Complex of use	-540.363	74.143	-7.288	<.001	.000
Lack of logical representation of projects-Inability to handle crashing tasks	-590.368	74.143	-7.963	<.001	.000
Lack of logical representation of projects-Non-prediction of project uncertainty	-596.363	74.143	-8.043	<.001	.000
Lack of logical representation of projects-Impossibility in managing complex projects	599.627	74.143	8.087	<.001	.000
Lack of logical representation of projects-Less tracking of projects	615.279	74.143	8.299	<.001	.000
Lack of logical representation of projects-High maintenance and implementation cost	-645.863	74.143	-8.711	<.001	.000
Lack of logical representation of projects-Needs supportive tools	-659.334	74.143	-8.893	<.001	.000
Lack of logical representation of	-668.849	74.143	-9.021	<.001	.000

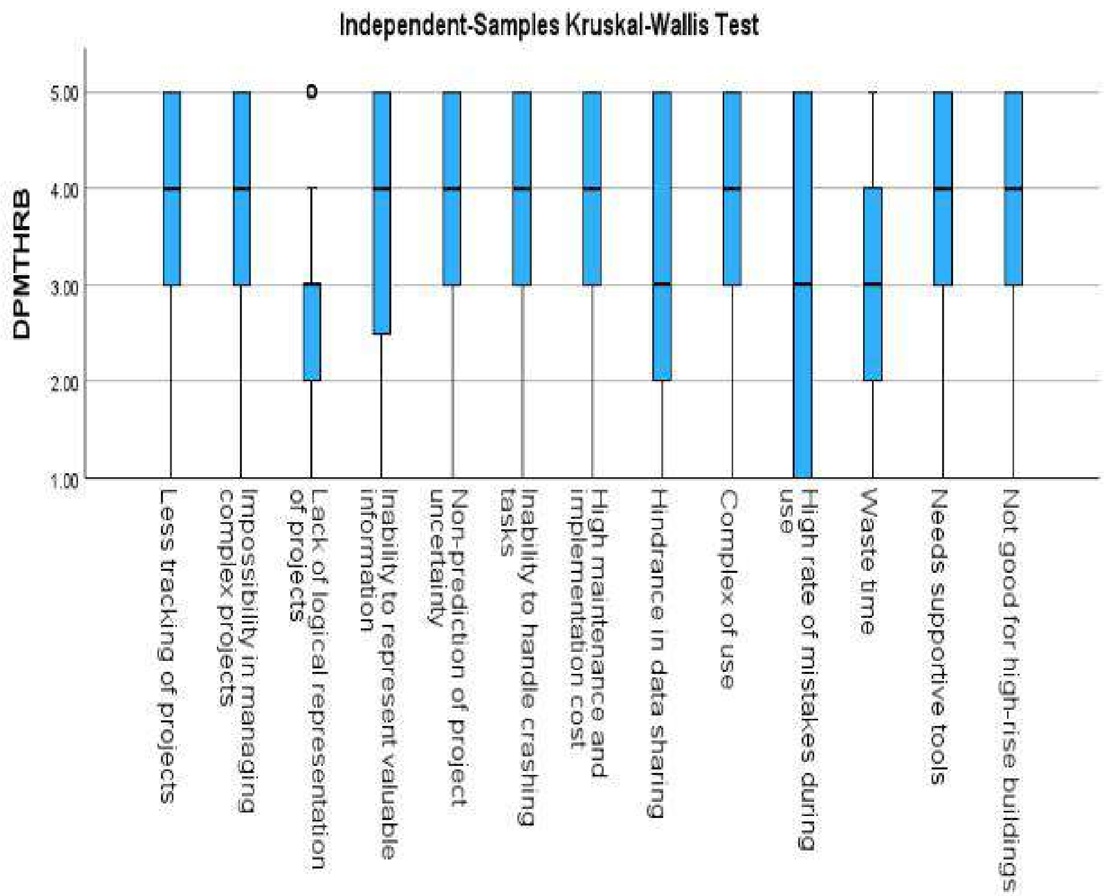
projects-Not good for high-rise buildings					
Hindrance in data sharing-Waste time	-68.012	74.143	-.917	.359	1.000
Hindrance in data sharing-High rate of mistakes during use	-107.214	74.143	-1.446	.148	1.000
Hindrance in data sharing-Inability to represent valuable information	302.820	74.143	4.084	<.001	.003
Hindrance in data sharing-Complex of use	-389.308	74.143	-5.251	<.001	.000
Hindrance in data sharing-Inability to handle crashing tasks	439.313	74.143	5.925	<.001	.000
Hindrance in data sharing-Non-prediction of project uncertainty	445.308	74.143	6.006	<.001	.000
Hindrance in data sharing-Impossibility in managing complex projects	448.572	74.143	6.050	<.001	.000
Hindrance in data sharing-Less tracking of projects	464.224	74.143	6.261	<.001	.000
Hindrance in data sharing-High maintenance and implementation cost	494.808	74.143	6.674	<.001	.000
Hindrance in data sharing-Needs supportive tools	-508.279	74.143	-6.855	<.001	.000
Hindrance in data sharing-Not good for high-rise buildings	-517.793	74.143	-6.984	<.001	.000
Waste time-High rate of mistakes during use	39.202	74.143	.529	.597	1.000
Waste time-Inability to represent valuable information	234.808	74.143	3.167	.002	.120
Waste time-Complex of use	321.296	74.143	4.333	<.001	.001
Waste time-Inability to handle crashing tasks	371.300	74.143	5.008	<.001	.000
Waste time-Non-prediction of project uncertainty	377.296	74.143	5.089	<.001	.000
Waste time-Impossibility in managing complex projects	380.560	74.143	5.133	<.001	.000
Waste time-Less tracking of projects	396.212	74.143	5.344	<.001	.000
Waste time-High maintenance and implementation cost	426.796	74.143	5.756	<.001	.000
Waste time-Needs supportive tools	-440.267	74.143	-5.938	<.001	.000
Waste time-Not good for high-rise buildings	-449.781	74.143	-6.066	<.001	.000
High rate of mistakes during use-Inability to represent valuable information	195.606	74.143	2.638	.008	.650
High rate of mistakes during use-Complex of use	282.094	74.143	3.805	<.001	.011
High rate of mistakes during	332.099	74.143	4.479	<.001	.001

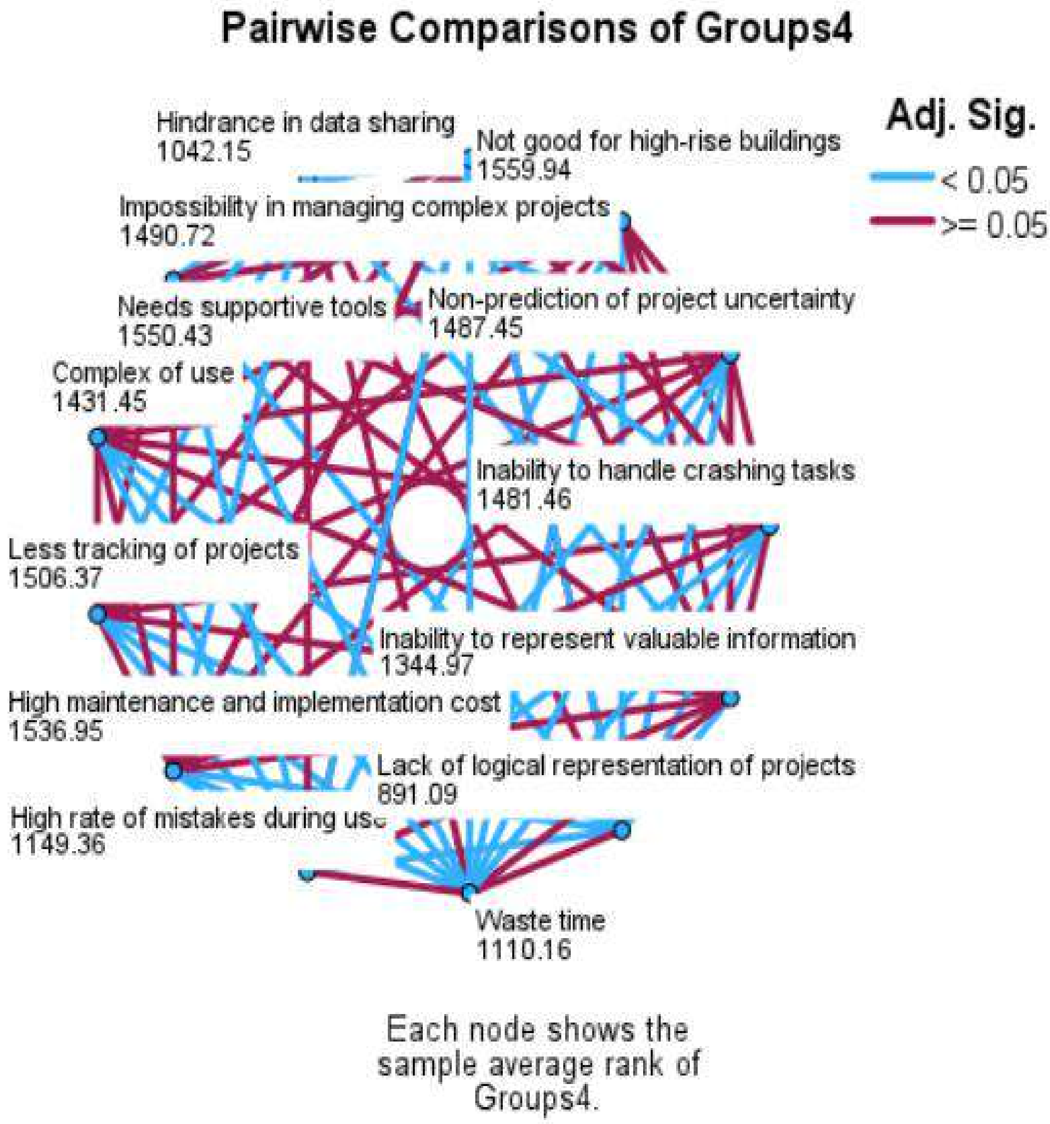
use-Inability to handle crashing tasks					
High rate of mistakes during use-Non-prediction of project uncertainty	338.094	74.143	4.560	<.001	.000
High rate of mistakes during use-Impossibility in managing complex projects	341.358	74.143	4.604	<.001	.000
High rate of mistakes during use-Less tracking of projects	357.010	74.143	4.815	<.001	.000
High rate of mistakes during use-High maintenance and implementation cost	387.594	74.143	5.228	<.001	.000
High rate of mistakes during use-Needs supportive tools	-401.065	74.143	-5.409	<.001	.000
High rate of mistakes during use-Not good for high-rise buildings	-410.579	74.143	-5.538	<.001	.000
Inability to represent valuable information-Complex of use	-86.488	74.143	-1.167	.243	1.000
Inability to represent valuable information-Inability to handle crashing tasks	-136.493	74.143	-1.841	.066	1.000
Inability to represent valuable information-Non-prediction of project uncertainty	-142.488	74.143	-1.922	.055	1.000
Inability to represent valuable information-Impossibility in managing complex projects	145.752	74.143	1.966	.049	1.000
Inability to represent valuable information-Less tracking of projects	161.404	74.143	2.177	.029	1.000
Inability to represent valuable information-High maintenance and implementation cost	-191.988	74.143	-2.589	.010	.750
Inability to represent valuable information-Needs supportive tools	-205.459	74.143	-2.771	.006	.436
Inability to represent valuable information-Not good for high-rise buildings	-214.974	74.143	-2.899	.004	.292
Complex of use-Inability to handle crashing tasks	50.005	74.143	.674	.500	1.000
Complex of use-Non-prediction of project uncertainty	56.000	74.143	.755	.450	1.000
Complex of use-Impossibility in managing complex projects	59.264	74.143	.799	.424	1.000
Complex of use-Less tracking of projects	74.916	74.143	1.010	.312	1.000
Complex of use-High maintenance and implementation cost	105.500	74.143	1.423	.155	1.000
Complex of use-Needs	-118.971	74.143	-1.605	.109	1.000

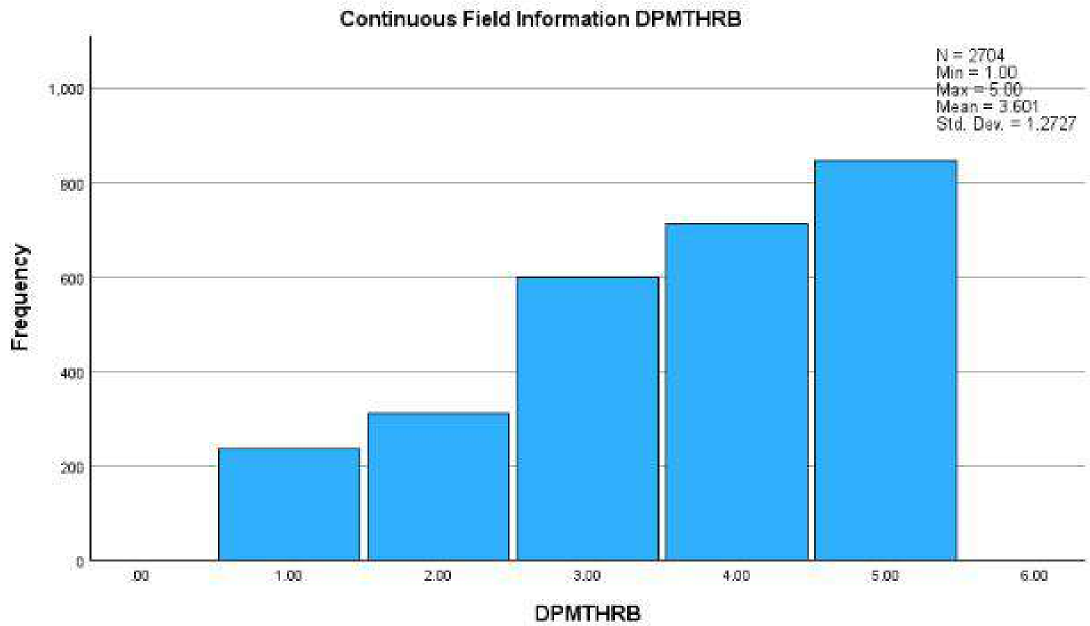
supportive tools					
Complex of use-Not good for high-rise buildings	-128.486	74.143	-1.733	.083	1.000
Inability to handle crashing tasks-Non-prediction of project uncertainty	5.995	74.143	.081	.936	1.000
Inability to handle crashing tasks-Impossibility in managing complex projects	9.260	74.143	.125	.901	1.000
Inability to handle crashing tasks-Less tracking of projects	24.911	74.143	.336	.737	1.000
Inability to handle crashing tasks-High maintenance and implementation cost	-55.495	74.143	-.748	.454	1.000
Inability to handle crashing tasks-Needs supportive tools	-68.966	74.143	-.930	.352	1.000
Inability to handle crashing tasks-Not good for high-rise buildings	-78.481	74.143	-1.059	.290	1.000
Non-prediction of project uncertainty-Impossibility in managing complex projects	3.264	74.143	.044	.965	1.000
Non-prediction of project uncertainty-Less tracking of projects	18.916	74.143	.255	.799	1.000
Non-prediction of project uncertainty-High maintenance and implementation cost	-49.500	74.143	-.668	.504	1.000
Non-prediction of project uncertainty-Needs supportive tools	-62.971	74.143	-.849	.396	1.000
Non-prediction of project uncertainty-Not good for high-rise buildings	-72.486	74.143	-.978	.328	1.000
Impossibility in managing complex projects-Less tracking of projects	15.651	74.143	.211	.833	1.000
Impossibility in managing complex projects-High maintenance and implementation cost	-46.236	74.143	-.624	.533	1.000
Impossibility in managing complex projects-Needs supportive tools	-59.707	74.143	-.805	.421	1.000
Impossibility in managing complex projects-Not good for high-rise buildings	-69.221	74.143	-.934	.350	1.000
Less tracking of projects-High maintenance and implementation cost	-30.584	74.143	-.413	.680	1.000
Less tracking of projects-Needs supportive tools	-44.055	74.143	-.594	.552	1.000
Less tracking of projects-Not	-53.570	74.143	-.723	.470	1.000

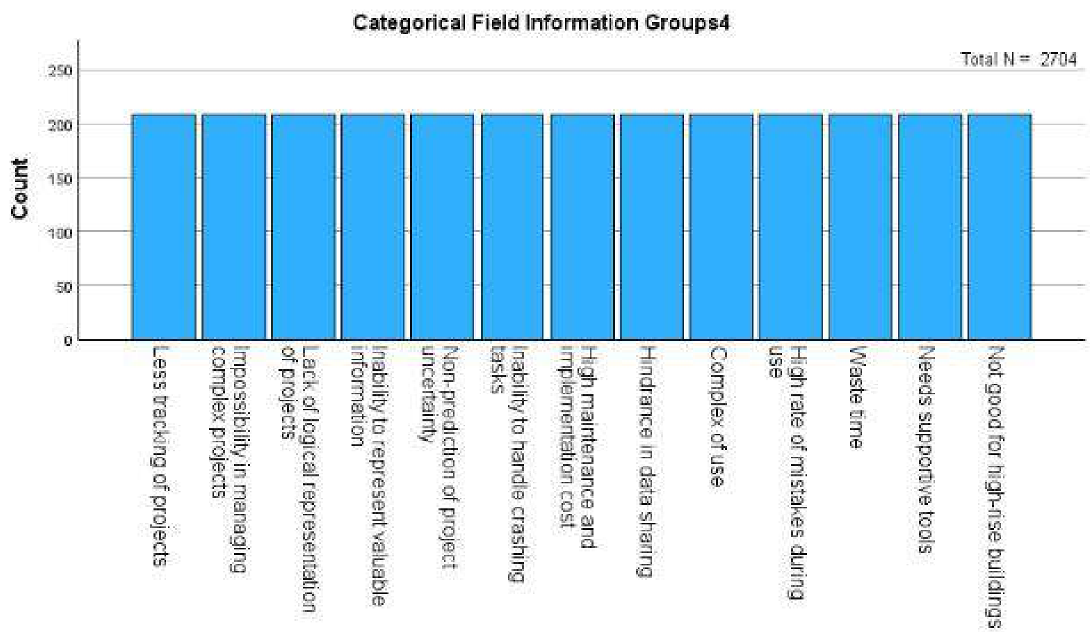
good for high-rise buildings					
High maintenance and implementation cost-Needs supportive tools	-13.471	74.143	-.182	.856	1.000
High maintenance and implementation cost-Not good for high-rise buildings	-22.986	74.143	-.310	.757	1.000
Needs supportive tools-Not good for high-rise buildings	-9.514	74.143	-.128	.898	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.




Pairwise Comparisons of Groups4
Adj. Sig.
< 0.05
>= 0.05
Hindrance in data sharing
1042.15
Not good for high-rise buildings
1559.94
Impossibility in managing complex projects
1490.72
Needs supportive tools
1550.43
Non-prediction of project uncertainty
1487.45
Complex of use
1431.45
Inability to handle crashing tasks
1481.46
Less tracking of projects
1506.37
Inability to represent valuable information
1344.97
High maintenance and implementation cost
1536.95
Lack of logical representation of projects
891.09
High rate of mistakes during use
1149.36
Waste time
1110.16
Each node shows the sample average rank of Groups4.


Continuous Field Information DPMTHRB
N = 2704
Min = 1.00
Max = 5.00
Mean = 3.601
Std. Dev. = 1.2727
Frequency
1,000
800
600
400
200
0
.00
1.00
2.00
3.00
4.00
5.00
6.00
DPMTHRB


Categorical Field Information Groups4
Total N = 2704
Count
250
200
150
100
50
0
Less tracking of projects
Impossibility in managing complex projects
Lack of logical representation of projects
Inability to represent valuable information
Non-prediction of project uncertainty
Inability to handle crashing tasks
High maintenance and implementation cost
Hindrance in data sharing
Complex of use
High rate of mistakes during use
Waste time
Needs supportive tools
Not good for high-rise buildings

Appendix VII
IBM SPSS Output Regarding Research Question Five and Hypothesis Five

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of CTTHRB is the same across categories of Groups5.	Independent-Samples Kruskal-Wallis Test	<.001	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Independent-Samples Kruskal-Wallis Test Summary

Total N	3952
Test Statistic	255.726[a]
Degree Of Freedom	18
Asymptotic Sig.(2-sided test)	<.001

a. The test statistic is adjusted for ties.

Pairwise Comparisons of Groups5

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
BIM + construction processes - BIM + query language	-382.010	108.582	-3.518	<.001	.074
BIM + construction processes - BIM + RFID	-499.659	108.582	-4.602	<.001	.001
BIM + construction processes - BIM + BLE	-698.962	108.582	-6.437	<.001	.000
BIM + construction processes - BIM + 4-Dimensional AR	-762.615	108.582	-7.023	<.001	.000
BIM + construction processes - BIM + OIP	-881.762	108.582	-8.121	<.001	.000
BIM + construction processes - BIM + digital programming	908.416	108.582	8.366	<.001	.000
BIM + construction processes - BIM + 3D IT	-912.798	108.582	-8.407	<.001	.000
BIM + construction processes - BIM + SWST + OIP	-913.702	108.582	-8.415	<.001	.000
BIM + construction processes - BIM + GIS	913.817	108.582	8.416	<.001	.000
BIM + construction processes - 4D BIM model	-917.132	108.582	-8.446	<.001	.000
BIM + construction processes - BIM + cost-based progress curves	-973.113	108.582	-8.962	<.001	.000
BIM + construction processes - BIM + GA + FEM	-976.168	108.582	-8.990	<.001	.000
BIM + construction processes - BIM + SWO + FCA	-1017.938	108.582	-9.375	<.001	.000
BIM + construction processes - BIM + UAVs + LST	-1021.168	108.582	-9.405	<.001	.000

BIM + construction processes - BIM + wireless sensors	-1094.308	108.582	-10.078	<.001	.000
BIM + construction processes - BIM + CPM	-1100.976	108.582	-10.140	<.001	.000
BIM + construction processes - BIM + EVA	-1108.406	108.582	-10.208	<.001	.000
BIM + construction processes - BIM environment + CES	-1188.450	108.582	-10.945	<.001	.000
BIM + query language-BIM + RFID	117.649	108.582	1.084	.279	1.000
BIM + query language-BIM + BLE	-316.952	108.582	-2.919	.004	.600
BIM + query language-BIM + 4-Dimensional AR	-380.606	108.582	-3.505	<.001	.078
BIM + query language-BIM + OIP	499.752	108.582	4.603	<.001	.001
BIM + query language-BIM + digital programming	526.406	108.582	4.848	<.001	.000
BIM + query language-BIM + 3D IT	-530.788	108.582	-4.888	<.001	.000
BIM + query language-BIM + SWST + OIP	-531.692	108.582	-4.897	<.001	.000
BIM + query language-BIM + GIS	531.808	108.582	4.898	<.001	.000
BIM + query language-4D BIM model	-535.123	108.582	-4.928	<.001	.000
BIM + query language-BIM + cost-based progress curves	-591.103	108.582	-5.444	<.001	.000
BIM + query language-BIM + GA + FEM	-594.159	108.582	-5.472	<.001	.000
BIM + query language-BIM + SWO + FCA	635.928	108.582	5.857	<.001	.000
BIM + query language-BIM + UAVs + LST	-639.159	108.582	-5.886	<.001	.000
BIM + query language-BIM + wireless sensors	-712.298	108.582	-6.560	<.001	.000
BIM + query language-BIM + CPM	-718.966	108.582	-6.621	<.001	.000
BIM + query language-BIM + EVA	-726.397	108.582	-6.690	<.001	.000
BIM + query language-BIM environment + CES	806.440	108.582	7.427	<.001	.000
BIM + RFID-BIM + BLE	-199.303	108.582	-1.836	.066	1.000
BIM + RFID-BIM + 4-Dimensional AR	-262.957	108.582	-2.422	.015	1.000
BIM + RFID-BIM + OIP	-382.103	108.582	-3.519	<.001	.074
BIM + RFID-BIM + digital programming	408.757	108.582	3.765	<.001	.029
BIM + RFID-BIM + 3D IT	-413.139	108.582	-3.805	<.001	.024
BIM + RFID-BIM + SWST + OIP	-414.043	108.582	-3.813	<.001	.023
BIM + RFID-BIM + GIS	414.159	108.582	3.814	<.001	.023

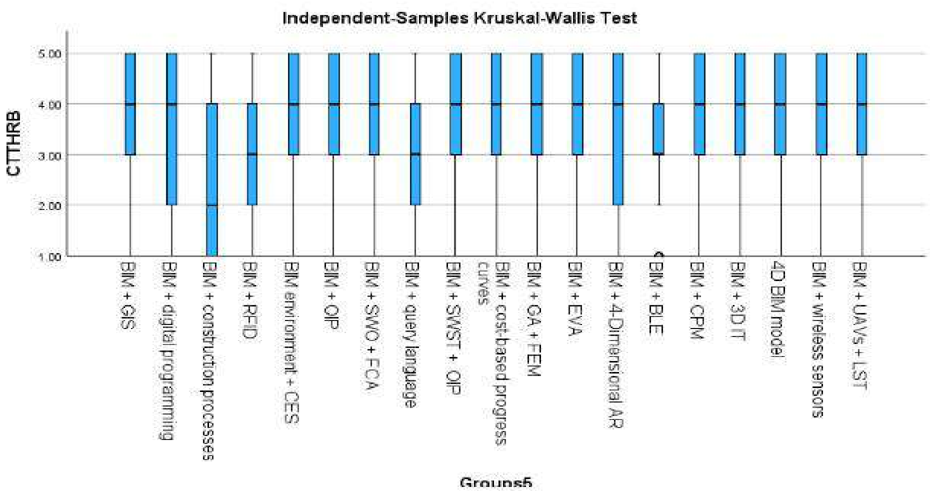
BIM + RFID-4D BIM model	-417.474	108.582	-3.845	<.001	.021
BIM + RFID-BIM + cost-based progress curves	-473.454	108.582	-4.360	<.001	.002
BIM + RFID-BIM + GA + FEM	-476.510	108.582	-4.388	<.001	.002
BIM + RFID-BIM + SWO + FCA	-518.279	108.582	-4.773	<.001	.000
BIM + RFID-BIM + UAVs + LST	-521.510	108.582	-4.803	<.001	.000
BIM + RFID-BIM + wireless sensors	-594.649	108.582	-5.477	<.001	.000
BIM + RFID-BIM + CPM	-601.317	108.582	-5.538	<.001	.000
BIM + RFID-BIM + EVA	-608.748	108.582	-5.606	<.001	.000
BIM + RFID-BIM environment + CES	-688.791	108.582	-6.344	<.001	.000
BIM + BLE-BIM + 4-Dimensional AR	63.654	108.582	.586	.558	1.000
BIM + BLE-BIM + OIP	182.800	108.582	1.684	.092	1.000
BIM + BLE-BIM + digital programming	209.454	108.582	1.929	.054	1.000
BIM + BLE-BIM + 3D IT	-213.837	108.582	-1.969	.049	1.000
BIM + BLE-BIM + SWST + OIP	214.740	108.582	1.978	.048	1.000
BIM + BLE-BIM + GIS	214.856	108.582	1.979	.048	1.000
BIM + BLE-4D BIM model	-218.171	108.582	-2.009	.045	1.000
BIM + BLE-BIM + cost-based progress curves	274.151	108.582	2.525	.012	1.000
BIM + BLE-BIM + GA + FEM	277.207	108.582	2.553	.011	1.000
BIM + BLE-BIM + SWO + FCA	318.976	108.582	2.938	.003	.565
BIM + BLE-BIM + UAVs + LST	-322.207	108.582	-2.967	.003	.514
BIM + BLE-BIM + wireless sensors	-395.346	108.582	-3.641	<.001	.046
BIM + BLE-BIM + CPM	-402.014	108.582	-3.702	<.001	.037
BIM + BLE-BIM + EVA	409.445	108.582	3.771	<.001	.028
BIM + BLE-BIM environment + CES	489.488	108.582	4.508	<.001	.001
BIM + 4-Dimensional AR-BIM + OIP	119.147	108.582	1.097	.273	1.000
BIM + 4-Dimensional AR-BIM + digital programming	145.800	108.582	1.343	.179	1.000
BIM + 4-Dimensional AR-BIM + 3D IT	-150.183	108.582	-1.383	.167	1.000
BIM + 4-Dimensional AR-BIM + SWST + OIP	151.087	108.582	1.391	.164	1.000
BIM + 4-Dimensional AR-BIM + GIS	151.202	108.582	1.393	.164	1.000
BIM + 4-Dimensional AR-4D BIM model	-154.517	108.582	-1.423	.155	1.000
BIM + 4-Dimensional AR-BIM + cost-based progress curves	210.498	108.582	1.939	.053	1.000
BIM + 4-Dimensional AR-BIM + GA + FEM	213.553	108.582	1.967	.049	1.000
BIM + 4-Dimensional AR-BIM + SWO + FCA	255.322	108.582	2.351	.019	1.000
BIM + 4-Dimensional AR-BIM + UAVs + LST	-258.553	108.582	-2.381	.017	1.000

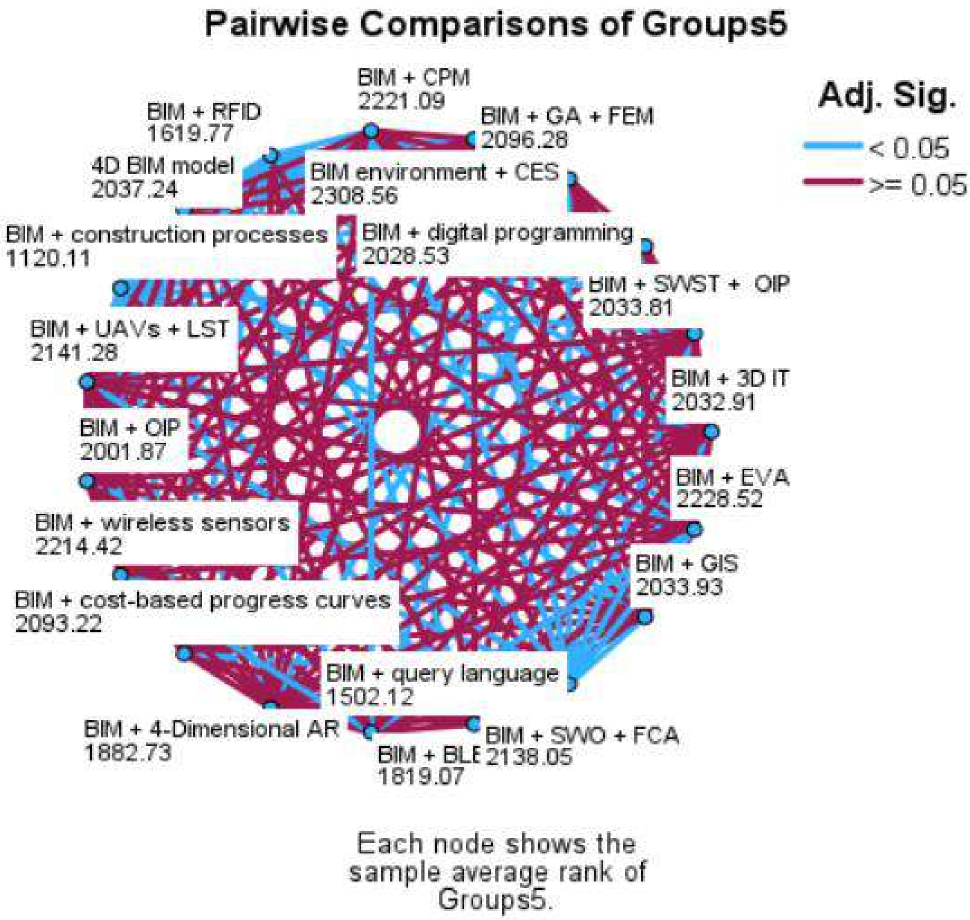
BIM + 4-Dimensional AR-BIM + wireless sensors	-331.692	108.582	-3.055	.002	.385
BIM + 4-Dimensional AR-BIM + CPM	-338.361	108.582	-3.116	.002	.313
BIM + 4-Dimensional AR-BIM + EVA	345.791	108.582	3.185	.001	.248
BIM + 4-Dimensional AR-BIM environment + CES	425.834	108.582	3.922	<.001	.015
BIM + OIP-BIM + digital programming	26.654	108.582	.245	.806	1.000
BIM + OIP-BIM + 3D IT	-31.036	108.582	-.286	.775	1.000
BIM + OIP-BIM + SWST + OIP	-31.940	108.582	-.294	.769	1.000
BIM + OIP-BIM + GIS	32.055	108.582	.295	.768	1.000
BIM + OIP-4D BIM model	-35.370	108.582	-.326	.745	1.000
BIM + OIP-BIM + cost-based progress curves	-91.351	108.582	-.841	.400	1.000
BIM + OIP-BIM + GA + FEM	-94.406	108.582	-.869	.385	1.000
BIM + OIP-BIM + SWO + FCA	-136.175	108.582	-1.254	.210	1.000
BIM + OIP-BIM + UAVs + LST	-139.406	108.582	-1.284	.199	1.000
BIM + OIP-BIM + wireless sensors	-212.546	108.582	-1.957	.050	1.000
BIM + OIP-BIM + CPM	-219.214	108.582	-2.019	.043	1.000
BIM + OIP-BIM + EVA	-226.644	108.582	-2.087	.037	1.000
BIM + OIP-BIM environment + CES	306.688	108.582	2.824	.005	.810
BIM + digital programming-BIM + 3D IT	-4.382	108.582	-.040	.968	1.000
BIM + digital programming-BIM + SWST + OIP	-5.286	108.582	-.049	.961	1.000
BIM + digital programming-BIM + GIS	5.401	108.582	.050	.960	1.000
BIM + digital programming-4D BIM model	-8.716	108.582	-.080	.936	1.000
BIM + digital programming-BIM + cost-based progress curves	-64.697	108.582	-.596	.551	1.000
BIM + digital programming-BIM + GA + FEM	-67.752	108.582	-.624	.533	1.000
BIM + digital programming-BIM + SWO + FCA	-109.522	108.582	-1.009	.313	1.000
BIM + digital programming-BIM + UAVs + LST	-112.752	108.582	-1.038	.299	1.000
BIM + digital programming-BIM + wireless sensors	-185.892	108.582	-1.712	.087	1.000
BIM + digital programming-BIM + CPM	-192.560	108.582	-1.773	.076	1.000
BIM + digital programming-BIM + EVA	-199.990	108.582	-1.842	.065	1.000
BIM + digital programming-BIM environment + CES	-280.034	108.582	-2.579	.010	1.000
BIM + 3D IT-BIM + SWST + OIP	.904	108.582	.008	.993	1.000
BIM + 3D IT-BIM + GIS	1.019	108.582	.009	.993	1.000

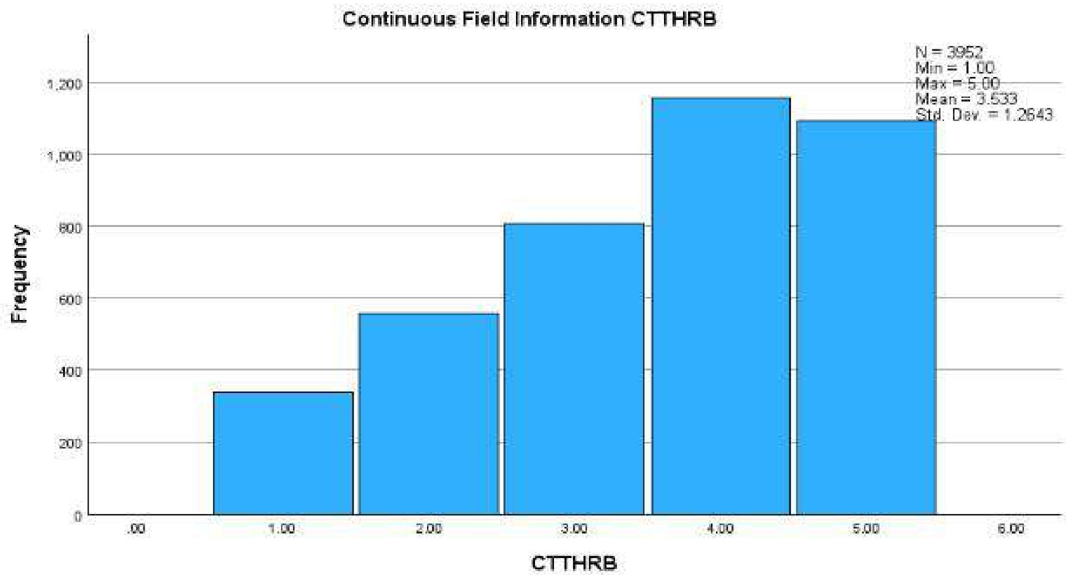
BIM + 3D IT-4D BIM model	-4.334	108.582	-.040	.968	1.000
BIM + 3D IT-BIM + cost-based progress curves	60.315	108.582	.555	.579	1.000
BIM + 3D IT-BIM + GA + FEM	63.370	108.582	.584	.559	1.000
BIM + 3D IT-BIM + SWO + FCA	105.139	108.582	.968	.333	1.000
BIM + 3D IT-BIM + UAVs + LST	-108.370	108.582	-.998	.318	1.000
BIM + 3D IT-BIM + wireless sensors	-181.510	108.582	-1.672	.095	1.000
BIM + 3D IT-BIM + CPM	188.178	108.582	1.733	.083	1.000
BIM + 3D IT-BIM + EVA	195.608	108.582	1.801	.072	1.000
BIM + 3D IT-BIM environment + CES	275.651	108.582	2.539	.011	1.000
BIM + SWST + OIP-BIM + GIS	.115	108.582	.001	.999	1.000
BIM + SWST + OIP-4D BIM model	-3.430	108.582	-.032	.975	1.000
BIM + SWST + OIP-BIM + cost-based progress curves	-59.411	108.582	-.547	.584	1.000
BIM + SWST + OIP-BIM + GA + FEM	-62.466	108.582	-.575	.565	1.000
BIM + SWST + OIP-BIM + SWO + FCA	104.236	108.582	.960	.337	1.000
BIM + SWST + OIP-BIM + UAVs + LST	-107.466	108.582	-.990	.322	1.000
BIM + SWST + OIP-BIM + wireless sensors	-180.606	108.582	-1.663	.096	1.000
BIM + SWST + OIP-BIM + CPM	-187.274	108.582	-1.725	.085	1.000
BIM + SWST + OIP-BIM + EVA	-194.704	108.582	-1.793	.073	1.000
BIM + SWST + OIP-BIM environment + CES	274.748	108.582	2.530	.011	1.000
BIM + GIS-4D BIM model	-3.315	108.582	-.031	.976	1.000
BIM + GIS-BIM + cost-based progress curves	-59.296	108.582	-.546	.585	1.000
BIM + GIS-BIM + GA + FEM	-62.351	108.582	-.574	.566	1.000
BIM + GIS-BIM + SWO + FCA	-104.120	108.582	-.959	.338	1.000
BIM + GIS-BIM + UAVs + LST	-107.351	108.582	-.989	.323	1.000
BIM + GIS-BIM + wireless sensors	-180.490	108.582	-1.662	.096	1.000
BIM + GIS-BIM + CPM	-187.159	108.582	-1.724	.085	1.000
BIM + GIS-BIM + EVA	-194.589	108.582	-1.792	.073	1.000
BIM + GIS-BIM environment + CES	-274.632	108.582	-2.529	.011	1.000
4D BIM model-BIM + cost-based progress curves	55.981	108.582	.516	.606	1.000
4D BIM model-BIM + GA + FEM	59.036	108.582	.544	.587	1.000
4D BIM model-BIM + SWO + FCA	100.805	108.582	.928	.353	1.000
4D BIM model-BIM + UAVs + LST	-104.036	108.582	-.958	.338	1.000
4D BIM model-BIM + wireless sensors	-177.175	108.582	-1.632	.103	1.000
4D BIM model-BIM + CPM	183.844	108.582	1.693	.090	1.000

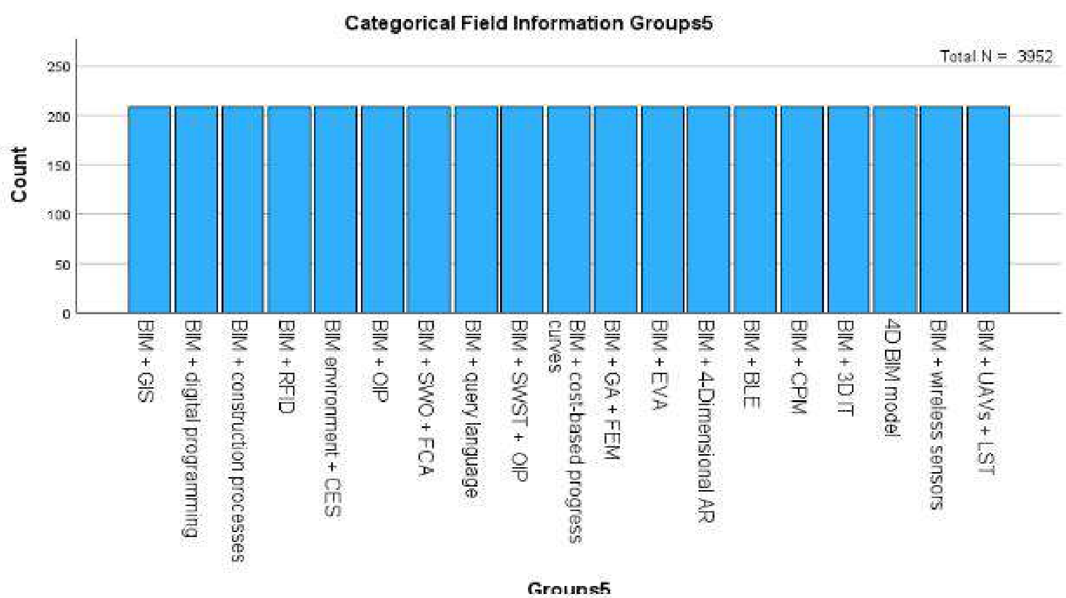
4D BIM model-BIM + EVA	191.274	108.582	1.762	.078	1.000
4D BIM model-BIM environment + CES	271.317	108.582	2.499	.012	1.000
BIM + cost-based progress curves-BIM + GA + FEM	-3.055	108.582	-.028	.978	1.000
BIM + cost-based progress curves-BIM + SWO + FCA	44.825	108.582	.413	.680	1.000
BIM + cost-based progress curves-BIM + UAVs + LST	-48.055	108.582	-.443	.658	1.000
BIM + cost-based progress curves-BIM + wireless sensors	-121.195	108.582	-1.116	.264	1.000
BIM + cost-based progress curves-BIM + CPM	-127.863	108.582	-1.178	.239	1.000
BIM + cost-based progress curves-BIM + EVA	-135.293	108.582	-1.246	.213	1.000
BIM + cost-based progress curves-BIM environment + CES	215.337	108.582	1.983	.047	1.000
BIM + GA + FEM-BIM + SWO + FCA	41.769	108.582	.385	.700	1.000
BIM + GA + FEM-BIM + UAVs + LST	-45.000	108.582	-.414	.679	1.000
BIM + GA + FEM-BIM + wireless sensors	-118.139	108.582	-1.088	.277	1.000
BIM + GA + FEM-BIM + CPM	-124.808	108.582	-1.149	.250	1.000
BIM + GA + FEM-BIM + EVA	-132.238	108.582	-1.218	.223	1.000
BIM + GA + FEM-BIM environment + CES	212.281	108.582	1.955	.051	1.000
BIM + SWO + FCA-BIM + UAVs + LST	-3.231	108.582	-.030	.976	1.000
BIM + SWO + FCA-BIM + wireless sensors	-76.370	108.582	-.703	.482	1.000
BIM + SWO + FCA-BIM + CPM	-83.038	108.582	-.765	.444	1.000
BIM + SWO + FCA-BIM + EVA	-90.469	108.582	-.833	.405	1.000
BIM + SWO + FCA-BIM environment + CES	170.512	108.582	1.570	.116	1.000
BIM + UAVs + LST-BIM + wireless sensors	73.139	108.582	.674	.501	1.000
BIM + UAVs + LST-BIM + CPM	79.808	108.582	.735	.462	1.000
BIM + UAVs + LST-BIM + EVA	87.238	108.582	.803	.422	1.000
BIM + UAVs + LST-BIM environment + CES	167.281	108.582	1.541	.123	1.000
BIM + wireless sensors-BIM + CPM	6.668	108.582	.061	.951	1.000
BIM + wireless sensors-BIM + EVA	14.099	108.582	.130	.897	1.000
BIM + wireless sensors-BIM environment + CES	94.142	108.582	.867	.386	1.000
BIM + CPM-BIM + EVA	7.430	108.582	.068	.945	1.000
BIM + CPM-BIM environment + CES	87.474	108.582	.806	.420	1.000
BIM + EVA-BIM environment + CES	80.043	108.582	.737	.461	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.




Pairwise Comparisons of Groups5
Adj. Sig.
< 0.05
>= 0.05
BIM + CPM
2221.09
BIM + RFID
1619.77
BIM + GA + FEM
2096.28
4D BIM model
2037.24
BIM environment + CES
2308.56
BIM + construction processes
1120.11
BIM + digital programming
2028.53
BIM + SWST + OIP
2033.81
BIM + UAVs + LST
2141.28
BIM + 3D IT
2032.91
BIM + OIP
2001.87
BIM + EVA
2228.52
BIM + wireless sensors
2214.42
BIM + GIS
2033.93
BIM + cost-based progress curves
2093.22
BIM + query language
1502.12
BIM + 4-Dimensional AR
1882.73
BIM + SWO + FCA
2138.05
BIM + BLE
1819.07
Each node shows the sample average rank of Groups5.


Continuous Field Information CTTHRB
N = 3952
Min = 1.00
Max = 5.00
Mean = 3.533
Std. Dev. = 1.2643
Frequency
1,200
1,000
800
600
400
200
0
.00
1.00
2.00
3.00
4.00
5.00
6.00
CTTHRB


Categorical Field Information Groups5
Total N = 3952
Count
250
200
150
100
50
0
BIM + GIS
BIM + digital programming
BIM + construction processes
BIM + RFID
BIM environment + CES
BIM + OIP
BIM + SWO + FCA
BIM + query language
BIM + SWST + OIP
BIM + cost-based progress curves
BIM + GA + FEM
BIM + EVA
BIM + 4-Dimensional AR
BIM + BLE
BIM + CPM
BIM + 3D IT
4D BIM model
BIM + wireless sensors
BIM + UAVs + LST
Groups5