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Analyzing the Effectiveness of Critical Path Methods in Project Performance: A Case Study of Building Projects in Lusaka's Metro Area

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Abstract

This study analyses the effectiveness of critical path methods on project performance taking a case study of building construction projects in the metro area of Lusaka. The study was guided by the following specific objectives namely; To assess the effectiveness of Critical Path Methods on Project Performance; To identify the relationship between Critical Path Methods and Project Performance and; To evaluate the limitations of Critical Path Methods on Construction Project Timelines. This was an exploratory case study research incorporating a mixed-methods approach structured with key research questions through a combination of both quantitative and qualitative methodologies. The sample size for the study was 50 Building professionals in the construction industry on active sites within the metro-area of Lusaka. These comprised of Architects, Project Managers, Engineers, Quantity Surveyors, Building Regulatory Officers and Contractors. Purposive Sampling was used in selecting the sample with primary data being collected through interview guides and questionnaires. The study in Lusaka's construction sector revealed that 86% of professionals aged 31-50 were familiar with Critical Path Methods (CPM), with universal awareness and 64% using it from the planning phase. Furthermore, CPM was found to improve scheduling accuracy (62%), communication (68%), and resource coordination, with Microsoft Project and Excel as preferred tools. It also enhanced cost control (86%), risk identification (68%), and overall project performance reducing delivery times (56%) and improving budget and quality outcomes. However, effectiveness depended on data quality (48%) and timely updates (62%). Training gaps (76%) and external disruptions (84%) were found to limit CPM's full potential, emphasizing the need for better tools and flexible planning strategies. In light of these findings, the research recommended; increased sensitization of CPM in building projects which will increase the number of projects benefitting from CPM; building capability through training and standardization leading to continuous improvement; strengthening roles, responsibilities and governance to foster an organization culture of all-round responsibility; development of robust Work Breakdown Structures to clearly outline the several activities expected on the projects. The study further recommended a future study on; comparative studies with alternative scheduling methods such as PERT, critical chain project management and others under varying project contexts and identifying conditions under which hybrid or tailored scheduling approaches may outperform pure CPM.

Keywords: Critical Path Methods, Project Duration, Critical Path, Project Delay and Float/Slack.

1.0 Introduction

1.1 Background

The Critical Path Method (CPM) is a project scheduling technique developed in the late 1950s that identifies the longest sequence of dependent tasks (the critical path) to determine the shortest possible project duration (Kerzner, 2022). CPM is widely used in construction due to its ability to Optimize scheduling by identifying task dependencies; Improve resource allocation by highlighting high-priority activities; Mitigate delays through early risk detection and Enhance cost control by preventing unnecessary expenditures. Globally, studies have demonstrated that projects using CPM experience 15–25% reduction in delays (PMI, 2021); 10–20% cost savings due to efficient resource management (Lock,

2020) and Higher stakeholder satisfaction due to predictable timelines (Harrison & Lock, 2017).
The demand for modern retail spaces in Lusaka has led to the development of several large-scale Construction projects such as shopping malls, Hotels, Hospitals and Mixed-use infrastructure. These projects involve complex construction processes, including Site preparation & foundation work; Structural framing & roofing; Mechanical, electrical, and plumbing (MEP) installations and Interior finishing & fit-out works.
The Zambian construction industry has experienced significant growth over the past decade, driven by urbanization, foreign direct investment (FDI), and government infrastructure development programs (World Bank, 2022). Lusaka, as the economic hub of Zambia, has seen a surge in commercial real estate projects as well as various other projects to meet the demands of a growing middle-class population and increasing consumer spending (Zambia Development Agency [ZDA], 2023). According to the National Council for Construction (NCC, 2023), the construction sector contributes approximately 12% to Zambia's GDP, with retail and mixed-use developments accounting for nearly 30% of private construction investments in urban areas.
However, despite this growth, the industry faces persistent challenges, including Project delays (averaging 6–12 months beyond scheduled completion); Cost overruns (exceeding budgets by 20–35%); Resource mismanagement (inefficient labor and material allocation) and Regulatory bottlenecks (lengthy approval processes and compliance issues). The industry faces challenges including skills shortages, material cost fluctuations, and bureaucratic hurdles (Zambia Institute of Architects, 2021).
These inefficiencies have been attributed to poor project planning, weak risk management, and reliance on traditional scheduling methods (Mulenga & Banda, 2022). Consequently, there is a growing need for advanced project management techniques to enhance efficiency and ensure timely project delivery.
Despite these benefits, CPM adoption in developing countries like Zambia remains limited due to Lack of skilled professionals trained in modern project management tools; Inadequate software and technological infrastructure; Resistance to change from traditional scheduling practices and Data inaccuracies leading to unreliable critical path calculations (Mwiya *et al*., 2021).
A study by the Engineering Institution of Zambia (EIZ, 2022) found that "Projects using CPM-based scheduling had 30% better adherence to timelines compared to those using bar charts or informal methods." However, challenges such as High software licensing costs; Limited training institutions offering CPM courses and Fragmented communication between contractors and subcontractors hinder widespread adoption.

1.2 Problem Statement
Despite the proven global effectiveness of the Critical Path Method (CPM) in enhancing construction project performance, its adoption remains limited in Zambia, with only 18% of construction firms systematically applying it (NCC, 2023). The low adoption rate is primarily driven by skills deficits, technological limitations, and cultural resistance to transitioning from traditional manual methods. Consequently, this underutilization of CPM has contributed to significant industry inefficiencies, including project delays (65%), cost overruns (25- 35%), reduced return on investment, increased financing costs, and diminishing contractor profit margins (ZDA, 2023). Therefore, the key problem is that the minimal application of CPM hampers project efficiency and performance, perpetuating the cycle of delays, cost overruns, and stakeholder dissatisfaction in the Zambian construction industry. This research aimed to address this gap by analyzing the effectiveness of CPM on project performance in the context of Lusaka.

1.3 Objectives
The general objective of this study was to analyze the effectiveness of Critical Path Methods in Project Performance taking a case study of Building Projects in Lusaka's Metro areas. To achieve this, the study focused on the following specific objectives: To assess the effectiveness of Critical Path Methods on Project Performance; To identify the relationship between Critical Path Methods and Project Performance; To evaluate the limitations of Critical Path Methods on Construction Project Timelines.

1.4 Research Questions
Furthermore, the study sought to answer the following specific research questions: What is the effectiveness of Critical Path Methods on Project Performance? What is the relationship between Critical Path Methods and Project Performance? What are the limitations of Critical Path Methods on Construction Project Timelines?

1.5 Theoretical Framework
The research adopted a framework that utilizes a project management theory namely the Critical Path Theory. This dates back to late 1950s and early 1960s and is a project management technique that identifies the longest sequence of dependent tasks (the critical path) to determine the shortest possible project duration. Critical Path Theory (CPT) is a fundamental technique in project management used to plan, schedule, and control complex projects as it assists in identifying the sequence of activities that determine the overall project duration, enabling efficient resource allocation and timely project completion (Kerzner, 2017).
It emphasizes the importance of task sequencing and resource allocation. This led to the birth of Critical Path Method (CPM) which was developed by
Morgan R. Walker and James E. Kelley, Jr. at DuPont. They introduced a systematic approach to project scheduling that included defining the critical path as the sequence of tasks that dictate the minimum project duration. Critical Path Theory involves analyzing the sequence of dependent tasks that form the critical path the longest chain of activities from project start to finish, which dictates the shortest possible completion time for the entire project (Milosevic, 2018). Critical path theory aids project managers in prioritizing tasks on the critical path, monitoring time-sensitive activities, and allocating resources effectively. It also helps in identifying potential delays and developing contingency plans, thus enhancing project control (Milosevic, 2018).

2.0 Literature Review
2.1 Effectiveness of Critical Path Methods on Project Performance
Critical Path Method (CPM) is a project management technique that identifies the longest sequence of dependent tasks in a project, determining the shortest possible project duration (Kerzner, 2017). CPM is particularly vital in

construction projects, where delays can be costly and impact overall project success. Understanding the critical path allows project managers to prioritize tasks, allocate resources effectively, and mitigate risks (Lock, 2020).
Its global adoption stems from its capacity to improve project efficiency, reduce costs, and mitigate delays, making it indispensable across industries such as construction, aerospace, manufacturing, and information technology. Since its inception, CPM has been intensively adopted across the globe, especially in large infrastructure and engineering projects. Its core principles which include identifying critical tasks, calculating project duration, and visualizing task dependencies have been integrated into many project management frameworks.
Across Africa, rapid infrastructural development driven by urbanization, population growth, and economic demands has increased the demand for structured project management approaches like CPM (Ogunlana *et al*., 2004). Nonetheless, the extent of its positive impact varies considerably due to unique socio-economic, organizational, and political factors that influence infrastructure and project management practices continent-wide. In recent decades, several African countries namely Nigeria, South Africa, Kenya, Ghana, and Ethiopia have incorporated CPM into their project management practices, especially in large infrastructure, energy, and resource-extraction projects (Akinola & Ojo, 2020).
CPM application in Zambia, a country with substantial infrastructural and developmental projects, has shown promise in improving project delivery through better planning and resource management. However, the actual effectiveness of CPM within the Zambian context is shaped by local factors such as capacity, infrastructure, policy environment, and socio- economic conditions. Zambia has increasingly adopted CPM in critical sectors such as infrastructure (roads, dams, energy facilities), mining, and urban development projects (Mulenga *et al*., 2018). Major government and private sector projects often leverage CPM to manage complex task sequencing, optimize resource utilization, and mitigate delays. While awareness of CPM exists among project managers and engineers, formal training remains limited.

2.2 Relationshipbetween CPM and Project Performance

Theoretically, effective application of CPM should improve project performance by optimizing timelines, reducing delays, and facilitating better resource management (Kerzner, 2017).
The relationship between the Critical Path Method (CPM) and project performance on a global scale reflects a fundamental connection where the effective application of CPM significantly influences project outcomes across diverse industries and regions. Globally, organizations and project managers utilize CPM as a systematic tool to optimize project planning, scheduling, and control, which in turn improves key performance indicators such as timeliness, cost efficiency, quality, and stakeholder satisfaction. CPM facilitates better coordination among international teams, suppliers, and stakeholders, especially in complex global projects such as infrastructure developments, energy projects, or construction initiatives that involve multiple countries and diverse regulatory environments.
Project performance within a regional context is generally measured by timeliness, cost adherence, quality, and stakeholder satisfaction. The relationship between CPM and project performance at a regional level is influenced by various factors such as capacity, institutional environment, socio-economic conditions, and sector-specific complexities. Regions that effectively implement CPM tend to have more predictable schedules, leading to improved project delivery timelines (Meredith & Mantel, 2011). nlana *et al*., 2004).
At the local level, CPM significantly influences project performance by providing a structured approach to planning and scheduling activities. By identifying the critical tasks that determine the minimum project duration, CPM enables project managers to optimize resource allocation, monitor progress, and swiftly address potential delays (Meredith & Mantel, 2011). This targeted focus helps ensure projects are completed within the agreed timeframe and budget, which are vital success indicators at the local level. The practical benefits of CPM are most apparent in environments where project management practices are mature, and personnel are trained in its application.

2.3 Limitations of CPM on Construction Project Timelines

Despite its widespread adoption, CPM has significant limitations when applied to global construction projects due to the dynamic, uncertain, and resource- intensive nature of the industry. Its practical usefulness is limited by data quality, uncertainty, resource constraints, change management, human factors, and limited integration with modern digital tools and risk management. These limitations are amplified in global projects due to heterogeneity in standards, markets, supply chains, regulatory environments, and project governance. Assumption of Fixed and Deterministic Activity Durations is one such challenge. CPM relies on deterministic scheduling, where each activity is assigned, a fixed duration based on historical data or expert judgment (Lock, 2020). This approach assumes that task durations are predictable and not subject to significant variation and External disruptions (e.g., weather, labor shortages) do not drastically alter timelines. In practice, construction projects especially those executed across different geographical regions face high uncertainty in task durations due to; Weather and environmental conditions. Projects in tropical regions (e.g., Southeast Asia) frequently experience delays due to monsoons, while Arctic projects face extreme cold halting work (Odeh & Battaineh, 2002). Supply chain disruptions: Global material shortages (e.g., steel, cement) and transportation delays (e.g., port congestions, customs clearance) can extend procurement timelines (Flyvbjerg, 2014). Labor productivity differences is another challenge. Failure to Account for Resource Constraints is also a challenge. CPM schedules tasks based solely on logical dependencies (i.e., Task B cannot start until Task A finishes).
While effective in stable, resource-rich environments, CPM's application in African construction projects reveals significant limitations. These include: Data quality and availability. CPM requires accurate activity durations, dependencies, and resource assumptions. In many African contexts, historical data may be sparse, informal, or poorly recorded, leading to inaccurate schedules and optimistic critical paths (Abou Rizk, 2006; Ogunsemi & Oyedele, 2018). Uncertainty and volatility of project parameters; Resource constraints and multi-project environments; Limited and fluctuating resources (labor, equipment, materials) cause dynamic reallocation pressures that CPM does not inherently handle, especially in environments with skilled-labor shortages or peak- season spikes (Opara *et al*., 2017); Change management and dynamic scope i.e. Frequent design changes and client-driven scope modifications are common in African projects, causing constant schedule revisions; Behavioral and organizational factors; Modeling limitations and integration with modern

practices; Regulatory and institutional constraints; External shocks and macro disruptions. While theoretically sound, CPM's implementation has revealed systemic limitations when applied to Zambia's unique construction ecosystem. These include; Data quality and availability; Inaccurate activity durations; Incomplete scope definition; Limited historical data; Resource constraints and leveling challenges; Change management and scope volatility; Complexity and manageability on large projects; Permits, approvals, and regulatory constraints; External dependencies and risk exposure; Local context and environmental factors; Software, skills, and data governance; Cultural and organizational alignment.

3.0 Research Methodology

3.1 Research Design/Methods/Approach

The Design approach used on this research was Exploratory Case Study Design which incorporated a mixed-methods approach structured to address specific research objectives and answered the key research questions through a combination of both quantitative and qualitative methodologies. The research targeted selected active Construction sites within the Metro areas of Lusaka City. The target population included the following: Project managers i.e. Individuals responsible for the planning, execution, and closing of construction projects; Architects i.e. Professionals who design building plans and ensure the project aligns with clients' requirements and regulatory standards (Wang *et al.*, 2019); Engineers involved in construction projects who design, develop, and maintain the structural aspects of a project; Quantity Surveyors i.e. Professionals who specialize in cost estimation and project budgeting; Contractors who are responsible for the physical execution of construction projects; Government officials and regulators who are representatives from municipal and national government bodies involved in managing and regulating construction activities, including licensing and compliance (Zarif *et al.*, 2020) and Consultants and advisors who are independent experts who provide specialized advice on project management, safety, and regulatory compliance within construction projects (Bokor *et al.*, 2019).

3.2 Triangulation, Sampling Design, Data Collection and Analysis

The study adopted stratified random sampling to ensure that specific subgroups within the target population were adequately represented and Purposive Sampling for selecting participants for qualitative interviews and focus group discussions. The sample size used in the research was fifty (50) and data was collected via distributed questionnaires and in-depth interviews prompting participants to share their insights and experiences with CPM in construction projects. The use of these two data sources ensured triangulation was maintained throughout the research. The collected data was analyzed using software such as STATA and Microsoft excel with statistical analysis using Chi-Square oodness-of-Fit test.

3.3 Ethical Considerations

This study adhered to ethical guidelines to ensure the protection of participants and the integrity of the research process (Mwansa 2020). Ethical considerations included: Informed Consent i.e. all participants were provided with an information sheet outlining the study's objectives, procedures, and potential risks; Confidentiality i.e. All data collected from participants was kept confidential with Personal identifiers were removed from survey responses and interview transcripts to protect participants' anonymity (Mutale 2021b); Voluntary Participation i.e. participation in the study was voluntary, and participants could withdraw at any time without any negative consequences (Kunda 2020).

4.0 Research Findings And Discussion of Results

4.1 Demographic Profile of Respondents

Understanding the background characteristics of respondents was crucial for interpreting the study's findings regarding the utilization and impact of Critical Path Methods (CPM) on construction projects in Lusaka's metro area. The sample size consisted of 50 respondents from various sectors within the construction industry in Lusaka's Metro area. The demographic profile was grouped into gender distribution, age, level of education, role played on the building project and professional experience in the construction industry. The data reveals that 20% of the respondents were female while 80% were male representing a male dominated workforce in the construction industry.

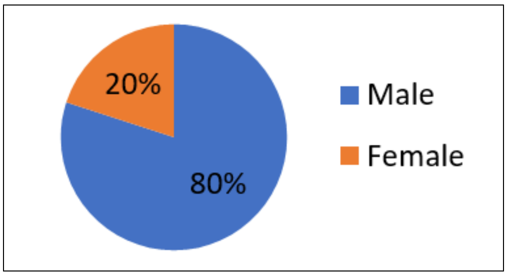

Fig 1.0: Percentage of Participants Gender

50% of the respondents were aged between 41-50 years representing an experienced group while 36% were aged between 31-40 years and 10% were between 21 and 30 years with only 4% aged above 50 years.

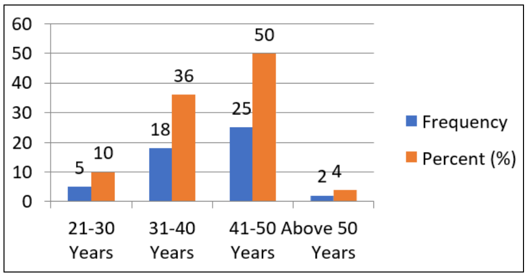

Fig 2.0: Age Distribution

Furthermore, 38% of the respondents had more than 15 years' experience, 34% had 10-15 years of experience, and 18% had 5-10 years' experience; 8% had 1-5 years' experience and only 2% had below 1year experience.

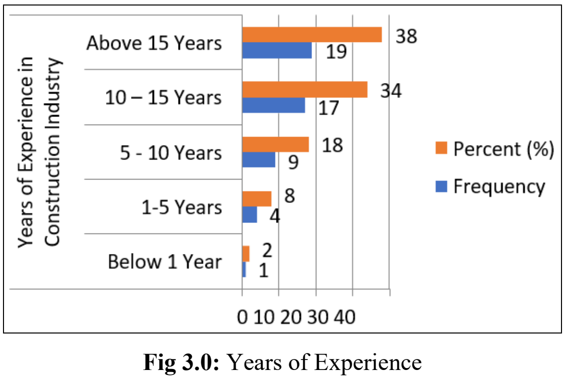

Fig 3.0: Years of Experience

Of the total number of respondents, 6% were at Doctorate level, 28% at Masters Level, 64% at Bachelor's level and 2% at Diploma level. This educational background and experience represents a knowledgeable and well trained sample base that presents a solid ground for the study's findings.

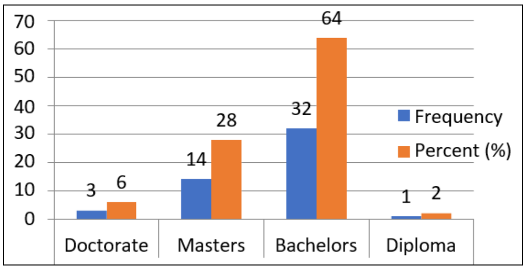

Fig 4.0: Level of Education

Regarding professional roles played by the respondents, 20% were Project Managers, 20% were Architects, 20% were Consultants, 20% site Engineers and 20% were Contractors.

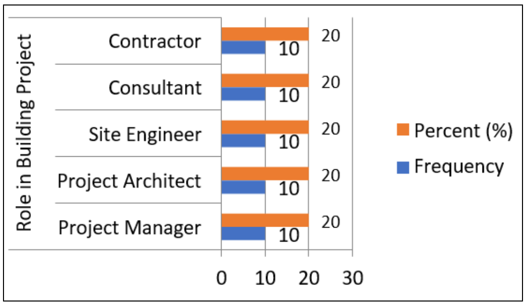

Fig 5.0: Professional Roles of Respondents

The roles represented those at the helm of implementing Critical Path Methods (CPM) on building projects.

4.2 Effectiveness of Critical Path Methods on Project Performance

Key themes that were identified include the level of awareness, adoption rates of CPM, methodologies employed, and the effectiveness of CPM in enhancing project management. Among the respondents, the level of awareness of CPM was established with 52% of the respondents confirming outright knowledge of CPM while 48% indicated knowledge of CPM in relation to Construction Programme of works. This in itself was evidence enough that 100% of the respondents working on Construction projects within Lusaka's metro area were knowledgeable of the concept of CPM.

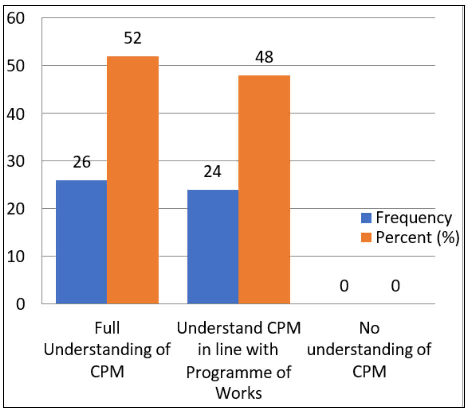

Fig 6.0: Level of CPM Awareness

When assessing the adoption rates of CPM on projects, it was revealed that 64% of the respondents adopted CPM from the onset of the Construction projects with 26% confirming use of manual scheduling methods only and 8% confirming that it was difficult to integrate CPM in the project as there was no clear outline of project completion date mainly due to lack of consistent and predictable cash flow due to Clients budgetary constraints.

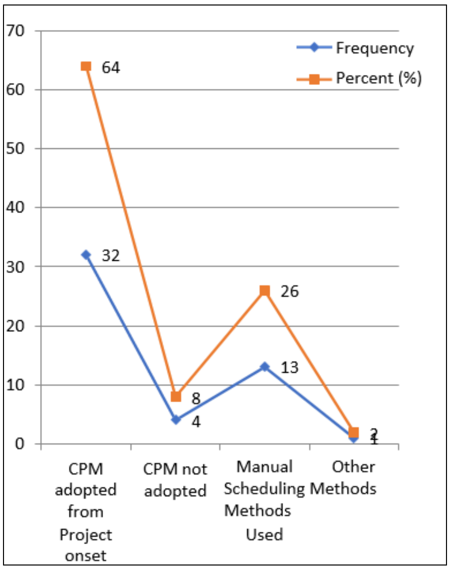

Fig 7.0: Level of CPM adoption rate

In assessing the relationship between the Project Schedule derived from CPM and the actual progress experienced on site, 62% of the respondents confirmed that the Project schedule derived from CPM accurately reflected the progress on site while 26% advised that project schedule did not reflect actual progress and milestones with 12% being indifferent. It therefore goes that majority of Construction Projects in Lusaka's Metro area have experienced positive results from use of CPM scheduling methods.

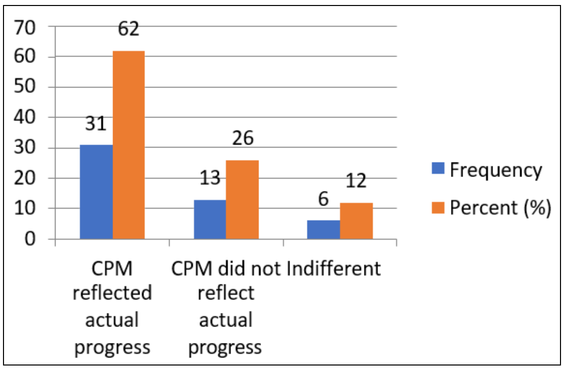

Fig 8.0: Relationship between CPM Project schedule and actual site progress

In accessing levels of communication of Critical path activities to the Project team, 68% of the respondents confirmed that the Critical Path and associated activities were communicated to the entire team on the project while 22% highlighted that these were only communicated to senior staff on the project and the remaining 10% confirmed that there was no communication at all to the Project team.

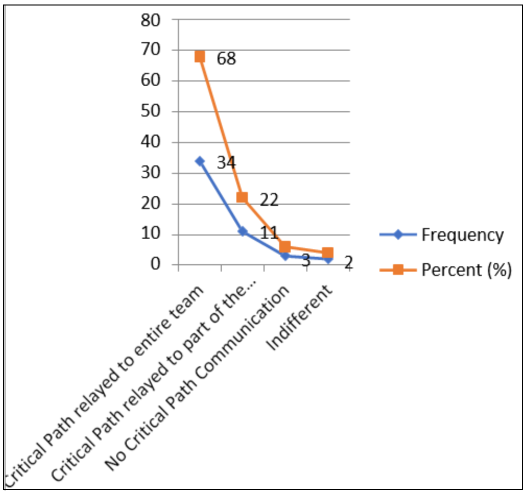

Fig 9.0: Communication of Critical Path

Regarding effective Communication methods on the projects, 68% confirmed receiving notification via in-person project meetings with 22% indicating receiving communication via email and 10% receiving communication via other means such as during ongoing work sessions.

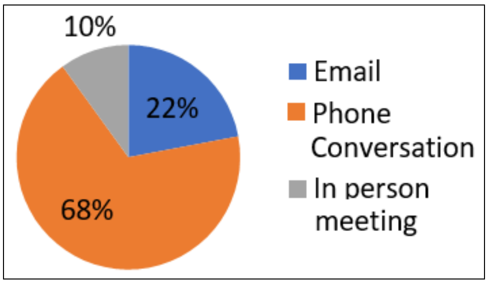

Fig 10.0: Method of Communication of Critical Path

To analyze the level of use of CPM software on Construction projects, 68% confirmed use of Microsoft Projects while 22% of the respondents used Microsoft Excel and only 10% using other software. These results confirm the wide use of Microsoft Projects and Excel software on Construction projects owing to the usability and availability of the software.

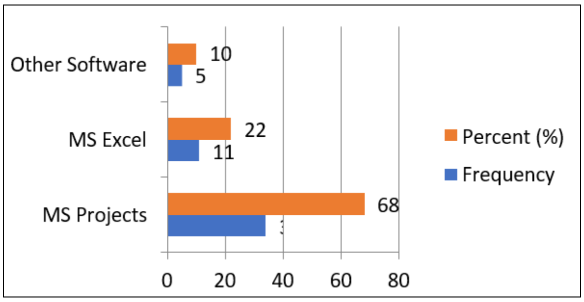

Fig 11.0: CPM Software employed

The research further on accessed the effectiveness of CPM on overall Project duration or earlier milestone achievement. 58% of the respondents confirmed that there had been a general improvement in planning and scheduling as a result of CPM while 30% where of the view that CPM had contributed to overall shorter project duration. 8% confirmed no difference in duration between use of CPM and non-use in relation to projects executed in the past while 4% could neither confirm nor deny the effectiveness of CPM on their projects.

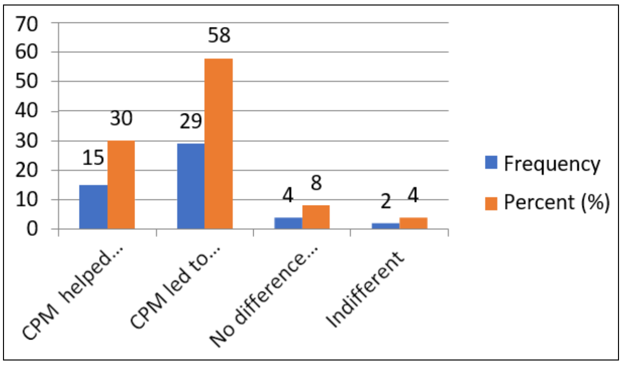

Fig 12.0: Effect of CPM on Project Duration

In establishing the effect of CPM on key project resources such as labor, equipment and materials by identifying constraints on the Critical Path, the research established that according to 36% of respondents, CPM had introduced efficiency on Labor resource use with a further 36% confirming that there was overall efficiency with CPM use on the project. 18% confirmed that CPM had properly guided material purchase and 10% opined that with CPM, Equipment was better utilized on the projects.

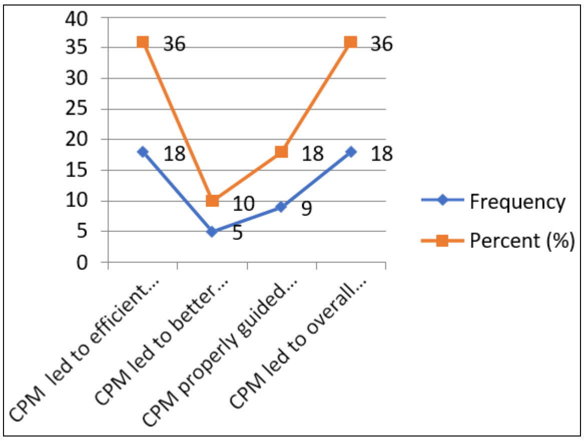

Fig 13.0: Effect of CPM on Key Project Resources

In assessing whether CPM contributed to better cost control through schedule-driven budgeting on the project, the research established through the respondents that according to 44% of respondents, CPM had contributed to Cost Control by linking the Schedule to the budget while 42% opined that CPM had contributed to Cost Control through early detection of cost drift while 14% confirmed that CPM had not contributed to Cost Control on their projects.

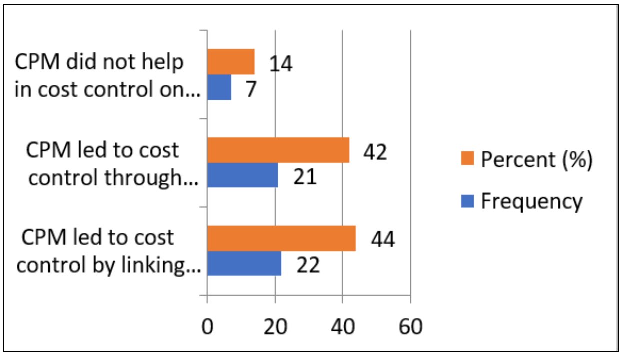

Fig 14.0: Relationship of CPM on Cost Control

In assessing whether CPM is effective in detecting schedule risks early and enabling proactive mitigation actions; 68% of the respondents confirmed that CPM helps to establish activities on the Critical Path which should not delay otherwise the whole project delays; 28% opined that CPM helped to affirm that any changes in the budget on any activity affected the project duration positively or negatively with 4% confirming that CPM was not effective in detecting schedule risks on their projects.

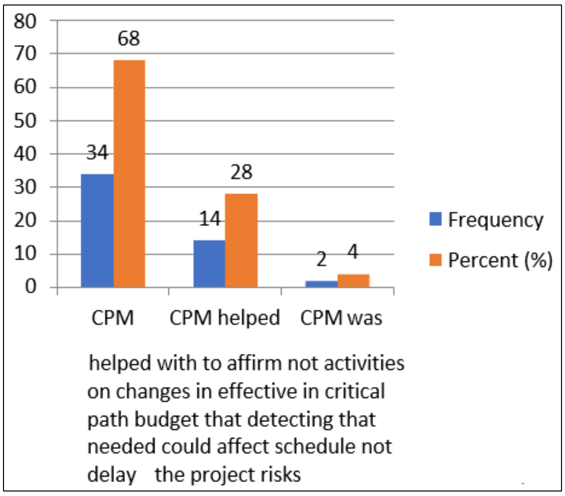

Fig 15.0: Effectiveness of CPM in detecting Schedule Risks

In establishing whether CPM facilitates better coordination among design teams, contractors, and suppliers, 66% of the respondents confirmed that CPM helped Architects, Engineers and Quantity Surveyors to coordinate better during Project Execution while 32% opined that CPM helped the Contractor to better manage suppliers as he was aware of activities on the Critical Path that needed no delay with only 2% confirming that CPM helped Project Managers to better deal with Regulatory Authorities as these were key in determining Project Duration especially regarding approvals.

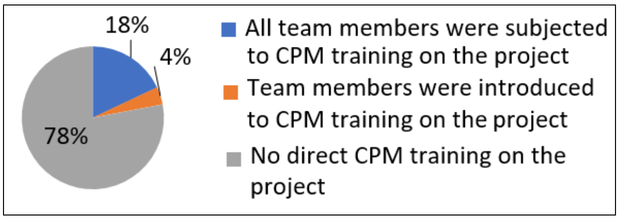

Fig 16.0: Level of Training on CPM on Construction Projects.

In assessing whether there was sufficient training on the project and organizational capability to sustain effective CPM usage i.e. tools, standards and methodologies, the research established the following; 78% confirmed that there was no direct CPM training on the project and that team members relied on personal research and knowledge while 18% confirmed that all team members were subjected to CPM training on the project while 4% confirmed that team members were introduced to CPM software on the projects.

4.3 Relationship between Critical Path Methods and Project Performance

Participants' responses provided great insights into establishment of the relationship between CPM and Project Performance in construction projects in Lusaka's Metro area. Understanding these attributes was crucial for improving the utilization of CPM in the construction industry. In assessing whether CPM had influenced overall project performance (on time delivery, cost control, and quality) on the project, 56% confirmed that the use of CPM on their projects had led to reduction in delivery period while 24% opined that the use of CPM had led to working within prescribed budget with 20% being of the view that the use of CPM had enhanced quality control on their projects.

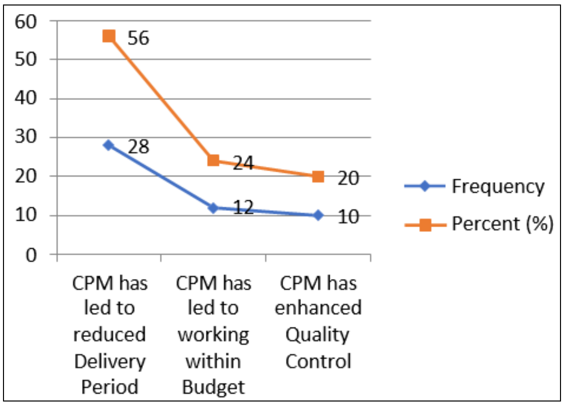

Fig 17.0: Effect of CPM on Project Performance

In establishing whether CPM had improved schedule reliability and reduced project duration compared to past projects without CPM, 64% confirmed that CPM had greatly improved Schedule reliability while 32% affirmed that CPM had helped reduce Project duration significantly with 4% arguing that CPM had not impacted schedule reliability and project duration in any way on their projects.

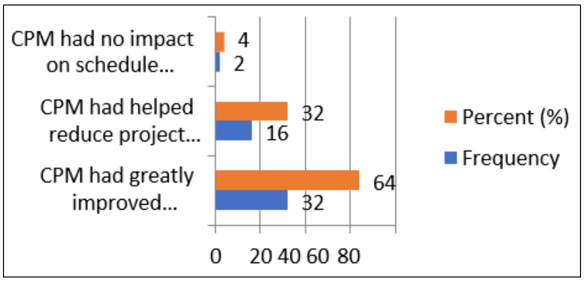

Fig 18.0: Effect of CPM on schedule reliability.

In determining whether CPM affected cost performance through better scheduling, sequencing, and resource allocation, 54% affirmed that resource allocation had led to better results in terms of Cost performance, 44% that there had been significant improvement of Cost performance through better scheduling and 2% arguing that there had been no difference at all on Cost performance resulting from CPM.

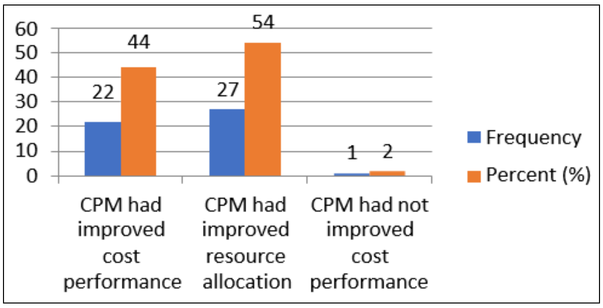

Fig 19.0: Effect of CPM on Cost Performance.

In assessing whether CPM helped to optimize resources (labor, equipment, materials) to enhance overall project performance, 64% advised that CPM had helped in optimal use of labor, equipment and materials on the project while

34% confirmed that there had been enhanced project performance due to use of CPM and 2% argued that the use of CPM had not improved Project performance.

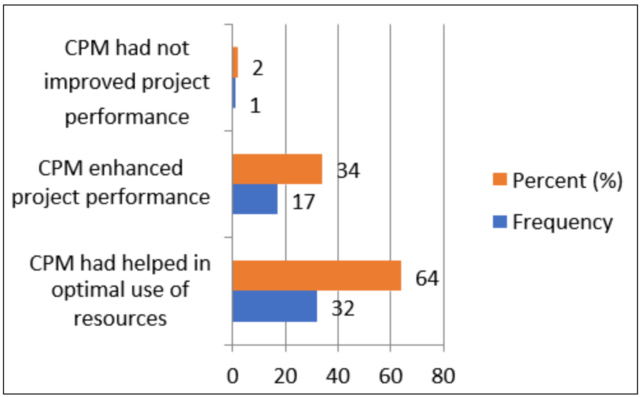

Fig 20.0: Effect of CPM on Resource Optimization.

The research proceeded to establish whether CPM was effective in early identification of schedule risks and enabling proactive mitigation actions that improved performance. 56% confirmed that CPM had made the Critical Path visible and clearly highlighted where risks mattered most while 44% opined that CPM's use of task dependency has helped to identify which delays would affect the project duration.

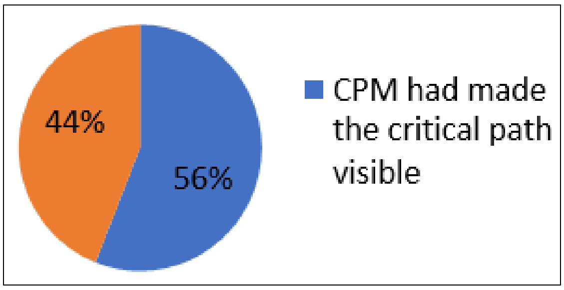

Fig 21.0: CPM and identification of schedule risks.

To assess whether CPM improved communication of critical activities and milestones to project Quality of input data was cardinal for CPM effectiveness Timeliness of data played a critical role in project duration Quality and timeliness played no critical role on CPM and Performance Percent (%) stakeholders thereby enhancing performance outcomes, 58% affirmed that CPM had helped in communication of critical activities to stakeholders and enhanced project performance while 42% indicated that CPM had helped stakeholders in decision making that impacted project duration.

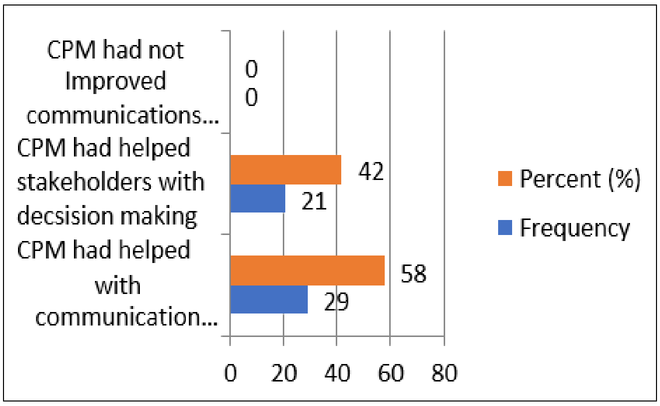

Fig 22.0: CPM's role in communication to Stakeholders

In establishing whether CPM's effectiveness was dependent on the quality and timeliness of input data (durations, dependencies and resources) for achieving desired performance, 48% affirmed that the quality of input data had been very cardinal in the effectiveness of CPM on their projects, 40% that timeliness of data had played a critical role in project duration and 12% that quality and timeliness of input data had no impact at all on CPM and project performance.

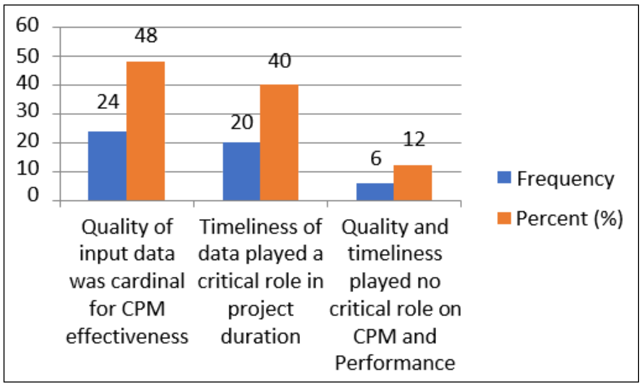

Fig 23.0: CPM's dependence on time and quality.

In assessing whether CPM facilitated coordination among designers, contractors, and suppliers to achieve better project performance, 52% confirmed that with CPM, the contractor had been able to align his Program of Works with Project duration while 48% opined that with CPM Architects, Engineers and Quantity Surveyors had been able to expedite their work to align with project duration.

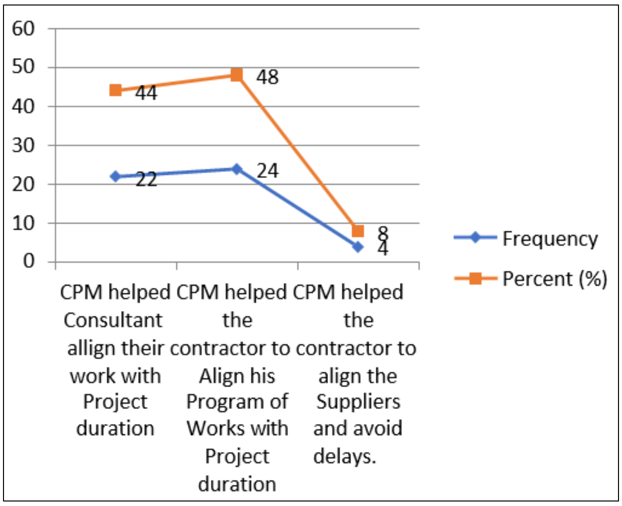

Fig 24.0: CPM's role in coordinating project team members.

Lastly, in establishing the relationship between CPM and project performance, a Chi-square goodness-of-fit test was conducted to assess whether the distribution of responses was statistically significant.

Table 1.0: Survey Results: Effects of CPM on Project Performance

Response Option	Frequency	Percentage
1. CPM has greatly improved schedule reliability	32	64%
2. CPM has helped reduce project duration significantly	16	32%
3. CPM has not impacted schedule reliability and project duration	2	4%
Total	50	100%

Table 2.0: Chi-Square Test Summary Table

Component	Value
Test Type	Chi-Square Goodness-of-Fit
Total Respondents	50
Degrees of Freedom (df)	2
Significance Level (α)	0.05
Critical Value ($\chi^2_{0.05,\ 2}$)	5.991
Calculated Chi-Square (χ^2)	27.03
p-value (approximate)	< 0.001
Decision	Reject Null Hypothesis
Interpretation	The distribution of responses is statistically significant; CPM is perceived to impact project performance.

The calculated chi-square value was 27.03, which exceeded the critical value of 5.991 at a 0.05 significance level (df = 2). This indicated a statistically significant preference toward CPM improving schedule reliability and reducing project duration. The results strongly suggest that respondents perceived CPM as a valuable tool for enhancing project performance confirming the relationship that exists between CPM and project performance.

4.4 Limitations of Critical Path Methods and Construction Project Timelines

The study explored several themes, including lack or availability of training, data quality challenges, openness or resistance to adoption, and organizational strengths or constraints. Understanding these attributes was crucial for improving the utilization of CPM in the construction industry.
In helping to establish whether data quality and availability (durations, dependencies, and resource constraints) limit the reliability of CPM-driven timelines on construction projects;76% confirmed that non-availability of necessary data greatly affected CPM-driven timelines with 24% opining that lack of quality data on dependent activities affected project duration.

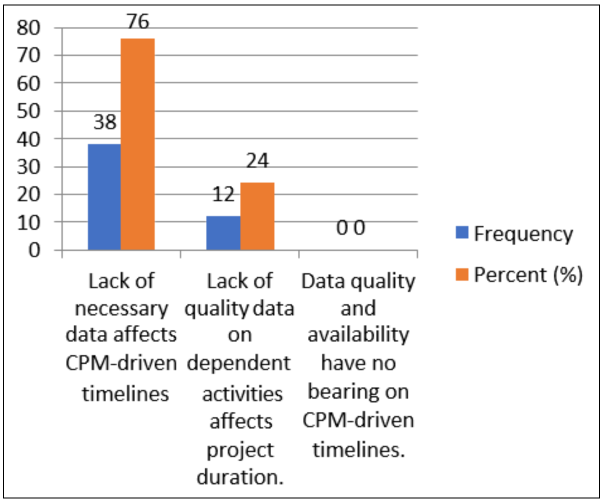

Fig 25.0: Data quality and limitations on CPM-Driven timelines

In assessing whether CPM adapted when design changed or late clarifications occurred, and how this affected timeline accuracy, 50% confirmed that changes in design have a negative bearing on project duration, 48% that CPM had been able to adapt in cases of design changes and late clarifications and 2% that CPM had not been able to adapt in case of design changes on the project.

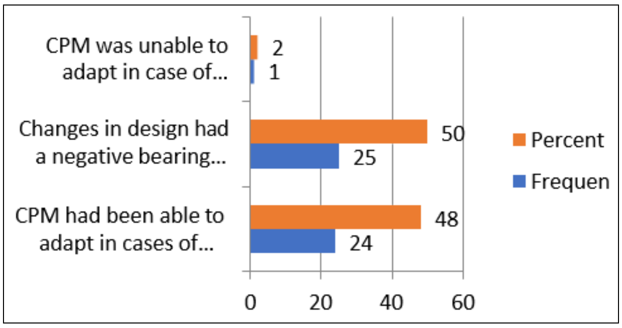

Fig 26.0: CPM's adaptation to design changes

The research sought to establish the performance of CPM in highly complex projects in capturing interdependencies across trades and phases, impacting timeline predictions. 42% affirmed that CPM has been very effective in capturing all interdependencies and has not affected timeline predictions; 32% that inaccurate time estimation between Contractors and Subcontractors for critical activities led to late material deliveries and 26% that CPM had not been effective hence affecting timeline predictions.

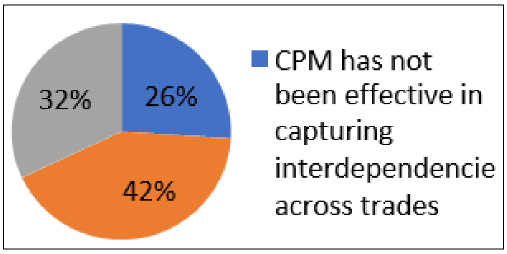

Fig 27.0: CPM and interdependencies

In determining whether the concept of float/slack in CPM was reliable for absorbing delays, given concurrent risks and multi-party schedules 72% confirmed that Float/Slack had been very reliable to absorb delays leading to timely project completion while 28% argued that Float/Slack did not play any role in absorbing delays on Critical Path activities on their projects and could not be relied upon.

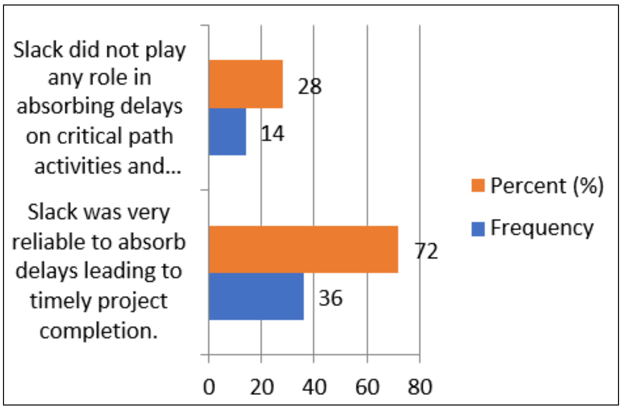

Fig 28.0: Reliability of Float/Slack in CPM on Construction Projects

In determining whether CPM adequately models limited resources (labor, equipment, materials) with no effect on critical path duration, 60% of respondents confirmed that CPM aided in optimization of all available resources with no effect on the Critical Path duration while 40% affirmed that despite CPM's optimization of resources, the project duration still got affected negatively.

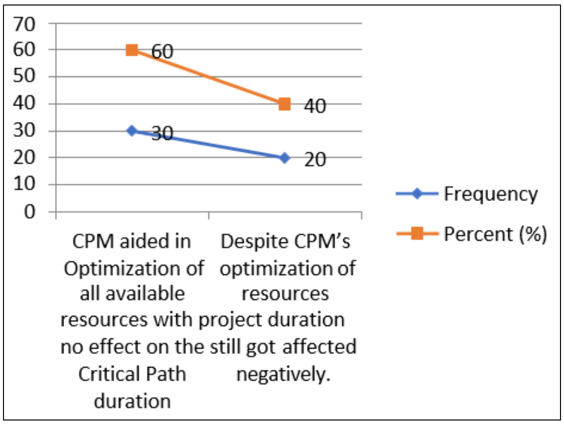

Fig 29.0: CPM and limited resources on Construction Projects

In determining whether CPM handles parallel activities and overlapping workflows well and whether this limits its timeline precision, 80% affirmed that CPM worked well in handling parallel activities and overlapping workflows while maintaining its timeline precision while 20% confirmed that CPM faced challenges in handling parallel activities and overlapping workflows leading to lagging behind on project duration.

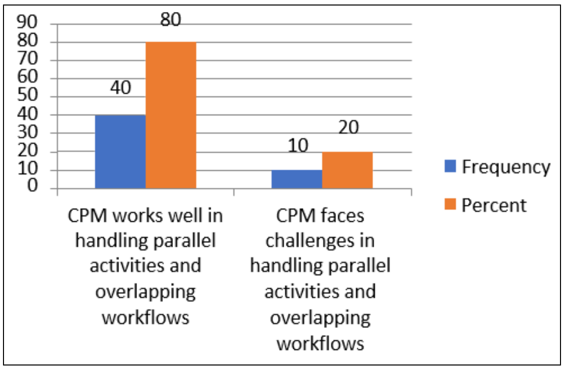

Fig 30.0: CPM and Overlapping Activities

The research proceeded to access whether CPM incorporates uncertainty (probabilistic durations, risk scenarios) effectively to which 56% of the respondents affirmed that CPM handled uncertainty with precision leading to attainment of estimated project duration while 44% confirmed that CPM did not fully anticipate uncertainty and this led to non- attainment of estimated project duration on their projects.

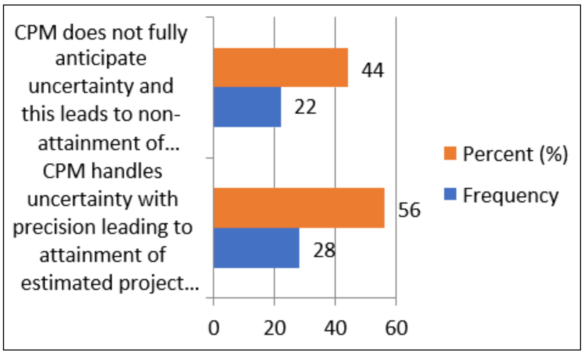

Fig 31.0: CPM and Uncertainty

The research delved into accessing the whether Human factors (training, discipline in updating schedules, adherence to standards) limit the effectiveness of CPM in producing accurate timelines. 76% confirmed that lack of CPM training on project contributed to inaccurate timelines while 12% argued that lack of discipline in updating of schedules led to project overrun with the remaining 12% affirming that lack of adherence to standards/building standards majorly affected project duration as it led to redoing of affected works.

The research further went on to determine the accessibility of CPM Software. 12% of the respondents indicated that CPM software was expensive to purchase and license hence not easily accessible while 78% affirmed that MS Excel and MS Projects were the ones mostly used on Construction projects as they are the ones that were easier to access with 10% indicating that It was difficult to use CPM software as there was limited software training available.

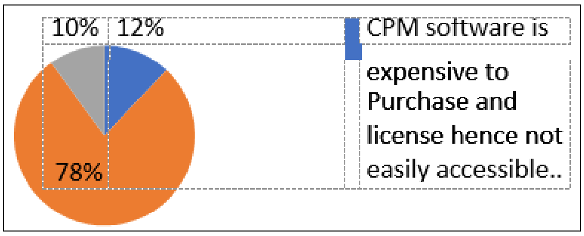

Fig 32.0: Accessibility of CPM Software

Lastly, the research sought to analyze whether Client Changes to Scope of Works and feedback from Regulatory Authorities lead to non-adherence to CPM. 52% of the respondents confirmed that Client creeps and changes to project scope affected duration of activities on the critical path while 32% confirmed that delayed approvals from Regulatory authorities affected activities on the Critical path leading to project delay and 16% indicated that lack of timely communication from the Client of changes in the budget affected the project duration.

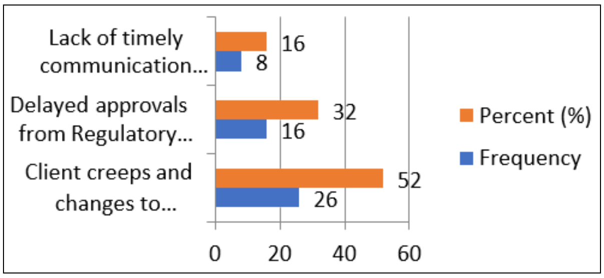

Fig 33.0: Effect of Client changes and Regulatory Authorities on CPM

5.0 Discussion

The study, centered on Lusaka's construction sector, highlights the perspectives of experienced professionals (86%) aged 31-50 on Critical Path Methods (CPM). It reveals universal awareness of CPM, with 52% having direct knowledge and 48% linking it to the Construction Programme of Works. While 64% implemented CPM from the planning phase, others relied on manual methods or faced budget-related integration issues. CPM was found to enhance scheduling accuracy (62%), communication (68% team-wide), and resource coordination. Microsoft Project (68%) and Excel (22%) were the preferred tools. CPM also improved cost control (86%) and risk identification (68%). However, 78% lacked formal training, indicating a need for capacity- building to maximize CPM's benefits. The study further confirms that Critical Path Method (CPM) improves project performance in Lusaka's construction sector. Key benefits include reduced delivery times (56%), better budget adherence (24%), and enhanced quality control (20%). CPM strengthens schedule reliability (64%), resource coordination (64%), and stakeholder communication (58%). It aids risk management through visibility of critical activities and task dependencies. However, effectiveness depends on data quality (48%) and timely updates (62%). Constraints include poor data, design changes, limited adaptability, and interdependency complexities. Despite widespread use of MS Project and Excel, training gaps (76%) and external disruptions (84%) hinder full CPM potential, highlighting the need for flexible planning, better tools, and improved organizational capability.

Conclusion

This study set out to evaluate the effectiveness, relationship and limitations of Critical Path Methods (CPM) in construction project management. Drawing from a diverse and experienced respondent base, the findings reveal a multifaceted picture of CPM's role in shaping project outcomes.

Firstly, CPM has proven to be a highly effective tool in enhancing project performance. A majority of respondents confirmed improvements in planning, scheduling, and resource coordination. CPM's structured approach to identifying critical activities and dependencies has enabled project teams to better manage timelines, reduce delays, and improve cost control. These outcomes are consistent with global literature, such as Bagshaw (2021) and Ezra *et al.* (2024), which affirm CPM's value in delivering projects on time and within budget.

Secondly, the study established a strong positive relationship between CPM and project performance. Respondents linked CPM usage to improved schedule reliability, enhanced quality control, and better stakeholder communication. The method's ability to visualize task dependencies and forecast project milestones has contributed to more informed decision-making and proactive risk management. This relationship underscores CPM's strategic importance in aligning project execution with organizational goals.

However, the research also uncovered critical limitations that constrain CPM's full potential. Data quality emerged as a major challenge, with inaccurate or unavailable input data undermining the reliability of CPM schedules. The method's rigidity in adapting to design changes, scope creep, and regulatory delays was also highlighted. Furthermore, human factors such as lack of training, poor schedule discipline, and limited software accessibility were found to significantly impact CPM's effectiveness. These limitations echo the concerns raised by Ökmen (2025) and Lima *et al.* (2023), who advocate for more flexible and integrated scheduling approaches.

Importantly, the study revealed that while CPM is widely adopted, its success is not solely dependent on the tool itself but on the organizational ecosystem in which it operates. Effective implementation requires accurate data, skilled personnel, supportive leadership, and robust communication channels. Without these elements, even the most sophisticated scheduling tools may fall short.

In conclusion, CPM remains a cornerstone of construction project management in Lusaka's Metro area. Its benefits are clear and measurable, but its limitations must be addressed through strategic interventions. By investing in training, improving data practices, and embracing hybrid scheduling models, the construction industry can unlock the full potential of CPM and drive more efficient, predictable, and successful project outcomes.

Recommendations

To enhance Critical Path Method (CPM) implementation in Lusaka's construction sector, six key recommendations are proposed. First, structured training is essential, as 78% of respondents lacked formal CPM education (Lima *et al.*, 2023). Second, improving data quality and timeliness is vital for reliable scheduling (Smartsheet, 2022). Third, adopting flexible tools like Critical Chain Project Management can address design and coordination challenges (Ökmen, 2025; Anastasiu *et al.*, 2023). Fourth, inclusive communication strategies should be promoted (Meegle, 2025). Fifth, proactive planning is needed to mitigate external disruptions (Ökmen, 2025). Lastly, resource optimization through integrated modeling can improve efficiency (Lima *et al.*, 2023). These steps will strengthen project outcomes.

Acknowledgements

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I am most grateful to my wife Wane Mwamengo and our children for their unwavering support, prayers and encouragement as well as my family, friends and classmates that made this journey a lot easier. Lastly, my gratitude goes to God Almighty for his unwavering grace and strength at every step of the way.

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