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Relationship Between Project Characteristics and Construction Mechanization in Kenya: A Survey of High-Rise Building Projects in Nairobi

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ABSTRACT: The construction industry in Kenya is a critical driver of economic growth, yet it continues to grapple with uneven adoption of mechanization across project categories. This study investigates the relationship between project characteristics (project value and project duration) and the level of mechanization in high-rise building projects in Nairobi. A quantitative survey design was employed, targeting accredited site supervisors, agents, and clerks of works overseeing projects worth more than KShs 100 million. Using Cochran's formula, a sample of 125 projects was selected, with 113 valid responses obtained, representing a 90.4% response rate. Data were analyzed using descriptive statistics, ANOVA, and Pearson's correlation to test the influence of project characteristics on mechanization levels across seven construction activities. The results reveal that project value significantly influences mechanization in structural and early-stage works, particularly site preparation, scaffolding/formwork, concreting, and building services, while finishing works such as plastering, tiling, and painting remain predominantly manual. Project duration similarly affects mechanization, with longer projects showing greater adoption in concreting, scaffolding, and walling, though correlation results highlight nuanced relationships, including a negative association with site preparation. These findings underscore that mechanization adoption in Kenya is uneven, shaped by financial capacity, project timelines, managerial choices, and technical constraints. The study contributes to the literature by providing empirical evidence from Kenya, aligning with global and regional findings that mechanization is concentrated in capital-intensive tasks but is less evident in finishing works. Policy implications include the need for targeted incentives, regulatory standards, and training programs to mainstream mechanization, while practical recommendations emphasize strategic planning, investment in equipment, and balanced labour–technology integration.

KEYWORDS: construction mechanization, high-rise buildings, project characteristics, survey.

1.0 INTRODUCTION

Mechanization in construction refers to the systematic adoption of machines and equipment to perform tasks traditionally executed by manual labour, to improve efficiency, precision, and safety (Hwang et al., 2020). Globally, mechanization has become a defining feature of modern construction, driven by the need to address labour shortages, rising costs, and demands for higher quality and faster project delivery. In advanced economies such as Europe, North America, and Asia, mechanization is deeply integrated into construction processes, ranging from earthmoving and concreting to advanced automation such as robotic bricklaying, 3D printing, and Building Information Modelling (Pan et al., 2018). These innovations have transformed construction into a capital-intensive industry, reducing reliance on manual labour while creating new demands for technical skills. However, scholars caution that mechanization also introduces risks of worker displacement, skill redundancy, and psychosocial stress if not accompanied by inclusive labour policies and structured training frameworks (Kapliński et al., 2002).

At the regional level in Africa, mechanization adoption remains uneven. Large infrastructure projects such as highways, bridges, and energy facilities increasingly rely on heavy equipment, yet small and medium-scale projects continue to depend heavily on manual labour (Adebowale & Agumba, 2022, 2023). Studies in Nigeria (Iheama et al., 2017) and South Africa (Mekgwe, 2016) highlight both opportunities and challenges: mechanization improves efficiency and site organization, but poor equipment maintenance, inadequate training, and weak safety protocols often lead to accidents and reduced worker welfare. This duality reflects broader structural issues in African economies, including high unemployment, reliance on informal labour markets, and limited access to advanced technologies. Mechanization is, therefore, not only a technical process but also a socio-economic transformation that must be managed holistically.

In Kenya, the construction industry is a critical driver of economic growth, contributing approximately 7% to GDP and playing a central role in the country's Vision 2030 development agenda (KNBS, 2023; Research and Markets, 2023). Nairobi, in particular, has witnessed rapid expansion in high-rise building projects, driven by urbanization, population growth, and demand for modern housing and commercial spaces. Yet, despite this growth, the level of mechanization remains relatively low, with most activities still relying on hand tools and semi-automated equipment. Recent surveys indicate that concreting and site preparation are among the most mechanized tasks, while finishing works such as plastering, painting, and building services remain predominantly manual (Ndolo et al., 2024). This uneven adoption reflects cost constraints, limited technical capacity, and weak regulatory enforcement.

Critically, project characteristics such as project value and project duration play a significant role in shaping mechanization levels. Higher-value projects often have the financial capacity to invest in advanced machinery, while longer-duration projects provide opportunities for structured mechanization planning and sustained training programs (Kulakov et al., 2023). Conversely, smaller and shorter projects tend to rely more on manual labour, reinforcing the persistence of low mechanization levels. This relationship underscores the importance of examining how project characteristics influence mechanization outcomes in Kenya's construction sector.

Against this backdrop, the present study investigates the relationship between project characteristics and construction mechanization in Nairobi's high-rise projects. By adopting a survey design, the study seeks to provide empirical evidence on how project value and duration influence mechanization levels across different construction activities. This study is a secondary analysis of the same dataset used in (Ndolo et al., 2024). The research is particularly significant given the gaps in existing literature, which often emphasize productivity metrics while neglecting the contextual determinants of mechanization. The study therefore contributes to a more holistic understanding of mechanization in Kenya's construction industry, offering insights for policy reform, organizational practice, and future research.

2.0 LITERATURE REVIEW

2.1 Global Perspectives on Construction Mechanization

Mechanization has long been recognized as a critical driver of productivity and efficiency in construction. In advanced economies, mechanization encompasses not only traditional heavy equipment such as cranes and excavators but also emerging technologies, including robotics, 3D printing, and Building Information Modelling (Pan et al., 2018). Studies show that mechanization reduces project timelines, enhances quality, and minimizes physical strain on workers (Hwang et al., 2020). However, scholars caution that mechanization can also disrupt labour markets, creating risks of job displacement and requiring new skill sets (Kapliński et al., 2002).

Project characteristics such as project value and duration are central to mechanization adoption globally. High-value projects often have the financial capacity to invest in advanced machinery, while longer projects provide opportunities for structured mechanization planning and sustained training programs (Kulakov et al., 2023). Conversely, smaller and shorter projects tend to rely more on manual labour, reinforcing uneven mechanization levels.

2.2 Regional Perspectives: Mechanization in Africa

In Africa, construction remains one of the most labour-intensive and hazardous industries. Mechanization adoption is uneven, with large infrastructure projects increasingly mechanized, while small and medium-scale projects continue to depend heavily on manual labour (O. J. Adebowale & Agumba, 2022, 2023). Research in Nigeria and South Africa highlights both opportunities and challenges: mechanization improves efficiency and site organization, but poor equipment maintenance, inadequate training, and weak safety protocols often lead to accidents and reduced worker welfare (Idoro, 2011; Iheama et al., 2017).

Scholars argue that project characteristics strongly influence mechanization outcomes in African contexts. Larger projects are more likely to adopt mechanization due to economies of scale, while longer projects allow for better integration of mechanized systems. However, weak regulatory enforcement, reliance on informal labour markets, and limited access to capital constrain mechanization adoption (Mitullah, 2021; Mitullah et al., 2021).

2.3 Mechanization in Kenya's Construction Industry

Kenya's construction sector contributes approximately 7% to GDP and plays a central role in the country's Vision 2030 development agenda (Research and Markets, 2023). Nairobi's rapid urbanization has spurred demand for high-rise projects, yet mechanization levels remain moderate. Studies indicate that concreting and site preparation are among the most mechanized tasks, while finishing works such as plastering, painting, and building services remain predominantly manual (Murianka et al., 2025).

Project characteristics are particularly influential in Kenya. High-value projects tend to invest in advanced machinery, while longer projects provide opportunities for structured mechanization planning and workforce training. However, smaller projects often rely on manual labour due to cost constraints, reinforcing uneven mechanization levels. (Kulakov et al., 2023) emphasize that digital technologies and lean tools can enhance mechanization effectiveness, but their adoption in Kenya remains limited.

2.4 Research Gap

Despite growing interest in mechanization, significant gaps remain in understanding its relationship with project characteristics in Kenya. Existing studies often emphasize productivity metrics while neglecting contextual determinants such as project value and duration. Moreover, most frameworks applied in Kenya are borrowed from Western contexts, with limited adaptation to local socio-economic realities such as informal labour markets and weak regulatory enforcement (Camarini et al., 2020). This raises questions about the validity and applicability of imported models in capturing the nuanced experiences of Kenyan construction projects.

This study addresses these gaps by empirically examining how project characteristics influence mechanization levels in Nairobi's high-rise projects. By focusing on project value and duration, the research provides a context-specific understanding of mechanization, contributing to both academic scholarship and practical policy reform.

3.0 METHODOLOGY

3.1 Research Design

This study adopted a quantitative strategy and a survey research design to investigate the relationship between project characteristics and mechanization in high-rise building projects in Nairobi. A survey design was appropriate because it enables the collection of standardized data from a relatively large sample, allowing for generalization to the wider population (Sekaran, 2003). The quantitative approach was chosen to provide measurable insights, enabling the testing of the research hypothesis.

3.2 Population and Unit of Analysis

The unit of analysis for this study was construction projects. The respondents for the survey, however, comprised accredited construction site supervisors who were required to answer questions regarding the construction project. These respondents were selected because they were academically competent to respond to the questionnaire. The target population was based on the number of registered construction projects. Therefore, the target population comprised accredited construction site supervisors, including site agents and clerks of works, who were directly involved in overseeing high-rise construction projects in Nairobi, Kenya.

3.3 Sampling Strategy and Sample Size

The target population was derived from the number of registered high-rise construction projects worth more than KShs 100 million, as listed by the National Construction Authority (NCA). A sample size of 125 projects was determined using Cochran's formula (Cochran, 1977) for large populations, adjusted with Bartlett's correction formula to account for finite population size (Bartlett et al., 2001). Simple random sampling was employed to ensure representativeness and minimize bias, giving each project an equal chance of selection.

$$n_o = \frac{t^2 \times s^2}{d^2} = \frac{1.96^2 \times 1.25^2}{0.15^2} = 266$$

Where;

- t = value for a selected alpha level of .025 in each tail = 1.96 (the alpha level of .05 indicates the level of risk the researcher is willing to take that the true margin of error may exceed the acceptable margin of error.)
- s = estimate of standard deviation in the population = 1.25. (estimate of variance deviation for 5-point scale calculated by using 5 [inclusive range of scale] divided by 4 [number of standard deviations that include almost all of the possible values in the range]).
- Where d = acceptable margin of error for mean being estimated = .15. (number of points on primary scale * acceptable margin of error; points on primary scale = 5; acceptable margin of error = .03 [error researcher is willing to except]).

In the second phase, the sample size is adjusted using the correction formula below. The adjustment applies because the estimated sample size exceeds 5% of the population (i.e., 235×5% = 12).

$$n = \frac{n_0}{1 + {}^{n_0}/_{Population}} = \frac{266}{1 + {}^{266}/_{235}} = 125$$

Where;

- n_o = 266 (Obtained from the Cochran's formula)
- Population size = 235. (Number of building projects worth more than KShs. 100 million registered by the National Construction Authority in Nairobi County)

Hence, n = **125** construction projects

3.4 Operationalization of Study Variables

The study comprises two main variables, namely, the project characteristics and construction mechanization. The former was broken down into project value and duration, which were measured in Kenyan shillings and weeks, respectively. Mechanization was operationalized as shown in Tables 1 and 2.

Table 1: Levels of Mechanization

Mechanization Level	Definition	Example
1-Completely manual	Workers are on-site and use non-machineries or simple tools without mechanisms to work	Shovel, saw, and hammer, etc.
2-Hand tool	Workers are on site and use equipment with mechanisms (but not machines)	Hand winch, claw hammer, and spirit level, etc.
3-Automated hand tool	Workers are on site and use machinery to work on the construction project	Electric laser leveler, electric drill, electric bolt wrench, etc.
4-Machine/ Workstation	Workers operate a machine/workstation to complete the construction task	Crane, excavator, and pump, etc.
5-Completely automated/Robotized	Workers are not required to operate or monitor the machine and the machine will complete the work activities by itself.	Robotic tiling machine, bricklaying robot, etc.

Source: (Hwang et al., 2020)

Table 2: Operational Definitions of Construction Mechanization

Variable	Operational Definition
Y: Extent of Construction Mechanization (M)	The degree to which construction processes and activities were mechanized, automated, or robotized, replacing traditional manual labour with machines and technology.
Y_1: Site Preparation and Earthworks (M_{SPE})	The extent to which construction processes and activities associated with Site Preparation and Earthworks were mechanized, automated, or robotized.
Y_2: Scaffolding and Formwork (M_{SF})	The extent to which construction processes and activities associated with Scaffolding and Formwork were mechanized, automated, or robotized.
Y_3: Concreting (M_C)	The extent to which construction processes and activities associated with Concreting were mechanized, automated, or robotized.

Variable	Operational Definition
Y_4: Walling (M_W)	The extent to which construction processes and activities associated with Walling were mechanized, automated, or robotized.
Y_5: Plastering and Flooring (M_{PF})	The extent to which construction processes and activities associated with Plastering and Flooring were mechanized, automated, or robotized.
Y_6: Tiling and Painting (M_{TP})	The extent to which construction processes and activities associated with Tiling and Painting were mechanized, automated, or robotized.
Y_7: Building Services (M_{BS})	The extent to which construction processes and activities associated with Building Services were mechanized, automated, or robotized.

(Own Formulation)

3.5 Data Collection

Data were collected using structured questionnaires administered physically at construction sites. The instrument comprised two sections: Part I, collecting background information (professional experience); Part II, collecting data on the project characteristics (project value and project duration); and Part III, focusing on the level of construction mechanization across the seven categories of construction works. The questionnaire was pilot-tested on a subset of 10 projects to refine clarity and ensure contextual relevance.

3.6 Data Analysis

Quantitative data were analyzed using SPSS version 25. Descriptive statistics (means, standard deviations, skewness, kurtosis) were used to summarize responses. Inferential statistics included Pearson's correlation to test construct validity and to examine relationships between construction mechanization and project characteristics. Reliability was assessed using Cronbach's Alpha, with values above 0.7 considered acceptable and values above 0.9 deemed excellent (Ahrens et al., 2020). ANOVA tests were also conducted to compare the means of mechanization levels across the project characteristics.

3.7 Ethical Considerations

Ethical clearance was obtained from Jomo Kenyatta University of Agriculture & Technology and the National Commission for Science, Technology and Innovation (NACOSTI). Respondents were assured of confidentiality, anonymity, and voluntary participation. Informed consent was sought prior to questionnaire administration, and data were stored securely to protect participant privacy.

4.0 RESULTS

4.1 Response Rate, Reliability, and Validity Tests

4.1.1 Response rate

A total of 125 questionnaires were administered physically to the randomly selected construction sites. A total of 116 questionnaires were received back (see Table 3). However, three of the questionnaires were discarded due to incompleteness. Two of these questionnaires had large sections left blank. Therefore, the number of usable questionnaires was 113, which was equivalent to a response rate of 90.4%. In these questionnaires, the number of missing values was negligible.

Table 3: Response Rate

Distributed	Total returned	Non-usable	Usable	Response rate	Remark
125	116	3	113	90.4%	Acceptable

4.1.2 Reliability Results

The reliability of the collected data was established using Cronbach's Alpha values obtained using SPSS version 25. The aim of this was to determine the internal consistency of the data. The results have been presented in Table 4. All the variables recorded values exceeding 0.9, which were deemed excellent. The overall Cronbach Alpha value was 0.958.

Table 4: Reliability Test Results

Variables	N of Items	Cronbach Value	Remarks
Site Preparation and Earthworks (M_{SPE})	11	0.857	Good
Scaffolding and Formwork (M_{SF})	18	0.951	Excellent
Concreting (M_C)	15	0.934	Excellent
Walling (M_W)	7	0.859	Excellent
Plastering and Flooring (M_{PF})	11	0.667	Acceptable
Tiling and Painting (M_{TP})	13	0.929	Excellent
Building Services (M_{BS})	13	0.654	Acceptable

4.1.3 Validity Results

The construct validity of the collected data was checked using Pearson's Product-Moment Correlation as advocated by (Karras, 1997). The validity test was conducted by correlating each variable with a newly computed variable (Total), which was the sum of all the variables under consideration. Significant relationships are an indication of the presence of validity (Ahrens et al., 2020). As presented in Table 5, all the variables were found to have construct validity.

Table 5: Construct and Criterion Validity Test Results

Variable		Total (Sum of the Variables)
Project Value	Pearson Correlation	0.314**
	Sig. (2-tailed)	0.001
Project Duration	Pearson Correlation	0.219*
	Sig. (2-tailed)	0.020
Level of Mechanization (M)	Pearson Correlation	0.042*
	Sig. (2-tailed)	0.046
**. Correlation is significant at the 0.01 level (2-tailed).		
*. Correlation is significant at the 0.05 level (2-tailed).		

4.2 Background Information

The background information collected for this study comprised the respondents' professional experience. The professional experience was grouped into five categories, namely: 1-5, 6-10, 11-15, 16-20, and above 20 years. The results are presented in Table 6. The highest frequency was recorded between 6-10 years (n=48, 42.5%) while the lowest was reported for the group above 20 years (n=9, 8%). Those with minimal professional experience of between 1-5 years were not considerably high, as they only had a frequency of 13 (11.5%). Since an overwhelming majority (n=100, 88.5%), it is evidently clear that the respondents had adequate experience and exposure in the construction industry to provide results rich in "validity".

Table 6: Professional experience

Years (n=113)	Frequency	%
1-5 Years	13	11.5
6-10 Years	48	42.5
11-15 Years	31	27.4
16 -20 Years	12	10.6
Above 20 Years	9	8.0

4.3 Project Characteristics

Two aspects were included in the project characteristics section. These included project value and project duration. Their results have been analyzed and discussed in the following sections.

4.3.1 Project Value

In this section, the researcher enquired about the current project value. The aim of this was to better understand the context and provide an explanation for the reported levels of mechanization, since high-value projects are expected to embrace machines and technology more than smaller projects. In this regard, the study only considered projects that were worth more than KShs 100 million. This is to avoid skewed results since very small projects would record negligible levels of mechanization and thus need a study on their own. The majority of the projects (n=103, 91.2%) had their contract sums between KShs 100 and 900 million, with only 10 (8.8%) being worth over KShs 100 million. As shown in Table 7, the highest frequency (n=43, 38.1%) was reported in "KShs 301-500 million", followed by "KShs 101-300 million" (n=28, 24.8%).

Table 7: Projects value

KShs (n=113)	Frequency	%
101 – 300million	28	24.8
301 – 500million	43	38.1
501 – 700million	21	18.6
701 – 900million	11	9.7
Above 900million	10	8.8
101 – 300million	28	24.8

4.3.2 Project Duration

The project duration was measured in weeks based on intervals of 36 weeks. As seen in Table 8, the results were fairly distributed, demonstrating a bell curve with the majority of the projects (n=97, 85.8%) lying between 37 and 144 weeks. Projects with durations below 36 weeks and above 144 weeks recorded frequencies of 7 (6.2%) and 9 (8.0%), respectively. The highest frequency was reported between 73-108 weeks (n=57, 50.4%).

Table 8: Projects duration

Weeks (n=113)	Frequency	%
Up to 36weeks	7	6.2
37-72weeks	24	21.2
73-108weeks	57	50.4
109-144weeks	16	14.2
Above 144weeks	9	8.0

4.4 Relationship between Project Characteristics and Construction Mechanization

4.4.1 Project Value versus Construction Mechanization

Table 9 presents the ANOVA results between project value and the mechanization of various work categories. Significant mechanization differences by project value were observed in site preparation, scaffolding/formwork, concreting, and building services. No significant differences were found in walling, plastering/flooring, and tiling/painting, indicating these remain largely manual regardless of project budget. The strongest influence of project value is on scaffolding and formwork (F=18.423), followed by concreting (F=4.200) and site preparation (F=3.677).

Table 9: ANOVA results between project value and Construction Mechanization

		Sum of Squares	df	Mean Square	F	Sig.
M_{SPE}	Between Groups	.673	4	.168	3.677	.008
	Within Groups	4.940	108	.046		
	Total	5.613	112			
M_{SF}	Between Groups	7.560	4	1.890	18.423	.000
	Within Groups	11.080	108	.103		
	Total	18.640	112			
M_C	Between Groups	1.986	4	.496	4.200	.003
	Within Groups	12.765	108	.118		
	Total	14.751	112			
M_W	Between Groups	.906	4	.226	1.736	.147
	Within Groups	14.083	108	.130		
	Total	14.989	112			
M_{PF}	Between Groups	.200	4	.050	2.120	.083
	Within Groups	2.544	108	.024		
	Total	2.744	112			
M_{TP}	Between Groups	.052	4	.013	.525	.717
	Within Groups	2.658	108	.025		
	Total	2.710	112			
M_{BS}	Between Groups	.188	4	.047	2.751	.032
	Within Groups	1.848	108	.017		
	Total	2.036	112			

M_{SPE}=Level of mechanization in Site Preparation and Earthworks; M_{SF}=Level of mechanization in Scaffolding and Formwork; M_C=Level of mechanization in Concreting; M_W=Level of mechanization in Walling; M_{PF}=Plastering and Flooring; M_{TP}=Level of mechanization in Tiling and Painting; M_{BS}=Level of mechanization in Building Services

Mechanization in site preparation and earthworks varies significantly ($F(4,108)=3.677$, $p=.008$) across project values. Higher-value projects are more likely to use heavy machinery (excavators, bulldozers) compared to lower-value projects, reflecting investment capacity in early-stage works. M_{SF} presented the strongest ($F(4,108)=18.423$, $p<.001$) result. Mechanization in scaffolding and formwork shows highly significant differences across project values. Larger projects invest more in mechanized formwork systems and scaffolding equipment, while smaller projects rely on manual assembly. Project value is, therefore, a critical determinant in this category. Concreting mechanization (e.g., batching plants, mixers, pumps) differs significantly ($F(4,108)=4.200$, $p=.003$) with project value. Higher-value projects adopt mechanized concreting methods to ensure speed and quality, while smaller projects rely more on manual mixing and placement. No statistically significant difference was found in M_W. Mechanization in walling (e.g., block-laying machines) is generally low across all project values, suggesting that walling remains predominantly manual regardless of budget size. In M_{PF}, differences are not statistically significant at the 0.05 level, though marginal ($F(4,108)=2.120$, $p=.083$). Mechanization in plastering and flooring is limited across projects, with manual labour still dominant. No significant difference was found in M_{TP}. Tiling and painting remain largely manual across all project values, reflecting low mechanization adoption in finishing works. Significant differences exist ($F(4,108)=2.751$, $p=.032$). Higher-value projects show greater mechanization in building services (e.g., HVAC installation, electrical/mechanical systems), while smaller projects rely more on manual methods.

Therefore, project value is a major determinant of mechanization in structural and early-stage works, but has limited impact on finishing works, which remain labour-intensive. This highlights a gap in mechanization adoption in Kenya's construction industry, where investment in advanced equipment is concentrated in high-budget structural tasks but not extended to finishing activities.

Table 10 presents Pearson correlation coefficients between project value and the level of mechanization across seven categories of construction activities. The results show both weak and moderate correlations, with only a few statistically significant relationships. Project value does not influence mechanization in site preparation and earthworks. This suggests that earthworks are mechanized consistently across projects, regardless of budget size. A weak and non-significant negative correlation was observed in M_{SF}. Project value has little to no effect on mechanization in scaffolding and formwork. This contrasts with ANOVA results (Table 6), which showed significant differences, suggesting that while group means differ, the linear relationship with project value is weak. A moderate, statistically significant negative correlation ($r = -0.311$, $p = .001$) was reported in M_C. Higher-value projects tend to show lower mechanization in concreting. This counterintuitive result may reflect reliance on specialized subcontractors or advanced manual techniques in high-budget projects, rather than direct mechanization. Weak, non-significant negative correlations were observed in M_W, M_{PF}, and M_{BS}. Mechanization in walling is generally low across all project values, confirming that walling remains predominantly manual regardless of budget. Also, project value does not significantly influence mechanization in plastering and flooring, which remain largely manual. Mechanization in tiling and painting is minimal across all project values. Project value does not significantly affect mechanization in building services.

This suggests that while ANOVA results (Table 9) showed differences in mechanization across project value groups, the overall linear relationship is weak. It means that project value influences mechanization in a categorical/grouped sense (larger projects differ from smaller ones), but the relationship is not consistently linear. Therefore, mechanization adoption in Kenya's construction industry appears to be influenced more by project type, managerial decisions, and technical capacity than by project value alone.

Table 10: Correlation between project value and Construction Mechanization

		Project Value	M_{SPE}	M_{SF}	M_C	M_W	M_{PF}	M_{TP}	M_{BS}
Project Value	Pearson Correlation	1	.009	-.081	-.311**	-.138	-.110	-.070	-.105
	Sig. (2-tailed)		.921	.392	.001	.145	.248	.460	.268
	N	113	113	113	113	113	113	113	113

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

M_{SPE}=Level of mechanization in Site Preparation and Earthworks; M_{SF}=Level of mechanization in Scaffolding and Formwork; M_C=Level of mechanization in Concreting; M_W=Level of mechanization in Walling; M_{PF}=Plastering and Flooring; M_{TP}=Level of mechanization in Tiling and Painting; M_{BS}=Level of mechanization in Building Services

4.4.2 Project Duration versus Construction Mechanization

Table 11 presents the ANOVA results between project duration and the mechanization of various work categories. Significant differences by project duration were found in site preparation, scaffolding/formwork, concreting, and walling. No significant differences in plastering/flooring, tiling/painting, and building services. The strongest influence of project duration is on concreting (F=13.219), followed by site preparation (F=6.984) and scaffolding/formwork (F=4.595). Therefore, longer projects are more conducive to mechanization in structural and early-stage works, where efficiency gains accumulate over time. Finishing works remain manual regardless of duration, reflecting cost constraints and limited mechanization technologies in Kenya.

Table 11: ANOVA results between Project Duration and Construction Mechanization

		Sum of Squares	df	Mean Square	F	Sig.
M_{SPE}	Between Groups	1.153	4	.288	6.984	.000
	Within Groups	4.459	108	.041		
	Total	5.613	112			
M_{SF}	Between Groups	2.711	4	.678	4.595	.002
	Within Groups	15.929	108	.147		
	Total	18.640	112			
M_C	Between Groups	4.848	4	1.212	13.219	.000
	Within Groups	9.903	108	.092		
	Total	14.751	112			
M_W	Between Groups	1.754	4	.439	3.579	.009
	Within Groups	13.235	108	.123		
	Total	14.989	112			
M_{PF}	Between Groups	.121	4	.030	1.241	.298
	Within Groups	2.623	108	.024		
	Total	2.744	112			
M_{TP}	Between Groups	.067	4	.017	.684	.605
	Within Groups	2.643	108	.024		
	Total	2.710	112			
M_{BS}	Between Groups	.160	4	.040	2.305	.063
	Within Groups	1.876	108	.017		
	Total	2.036	112			

M_{SPE}=Level of mechanization in Site Preparation and Earthworks; M_{SF}=Level of mechanization in Scaffolding and Formwork; M_C=Level of mechanization in Concreting; M_W=Level of mechanization in Walling; M_{PF}=Plastering and Flooring; M_{TP}=Level of mechanization in Tiling and Painting; M_{BS}=Level of mechanization in Building Services

Mechanization in site preparation and earthworks varies significantly ($F(4,108)=6.984$, $p<.001$) across project durations. Longer projects are more likely to invest in heavy machinery (excavators, bulldozers) because extended timelines justify the cost and efficiency gains. Significant differences ($F(4,108) = 4.595$, $p = .002$) exist in M_{SF}. Longer projects tend to adopt mechanized scaffolding and formwork systems to improve safety and efficiency, while shorter projects rely more on manual assembly. M_C presents the strongest result ($F(4,108) = 13.219$, $p < .001$). Mechanization in concreting (e.g., batching plants, pumps, mixers) is highly influenced by project duration. Longer projects are more likely to mechanize concreting to ensure consistency and speed over extended timelines. Significant differences ($F(4,108) = 3.579$, $p = .009$) are also observed in M_W. Longer projects show greater mechanization in walling, though the effect is weaker compared to concreting and site preparation. Mechanization in building services shows a slight variation ($F(4,108) = 2.305$, $p = .063$) with project duration, but the evidence is weak. No statistically significant difference was noted in M_{PF} and M_{TP}. Plastering and flooring remain largely manual across projects, regardless of duration. Tiling and painting are consistently manual across projects of varying durations.

The results of the Pearson correlation between the project duration and mechanization have been presented in Table 12. Significant correlations were observed in M_{SPE} and M_C. A moderate negative correlation in site preparation and earthworks meant that longer projects were associated with less mechanization. This suggests that extended projects may rely more on manual labour for preliminary works, possibly due to cost-saving strategies or phased deployment of equipment. On the other hand, a positive correlation in concreting meant that longer projects were associated with more mechanization. It is evident that project duration influences mechanization unevenly. Longer projects are more likely to mechanize concreting activities (e.g., batching plants, pumps, mixers). This reflects the efficiency gains needed in extended projects where large volumes of concrete must be placed consistently over time. Therefore, longer projects reduce mechanization in early-stage works (site preparation) but increase mechanization in structural works (concreting). Finishing activities remain manual regardless of duration.

Table 12: Correlation between Project Duration and Construction Mechanization

		Project Duration	M_{SPE}	M_{SF}	M_C	M_W	M_{PF}	M_{TP}	M_{BS}
Project Duration	Pearson Correlation	1	-.338**	-.149	.247**	.084	.076	-.001	-.112
	Sig. (2-tailed)		.000	.116	.008	.374	.425	.993	.236
	N	113	113	113	113	113	113	113	113

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

M_{SPE}=Level of mechanization in Site Preparation and Earthworks; M_{SF}=Level of mechanization in Scaffolding and Formwork; M_C=Level of mechanization in Concreting; M_W=Level of mechanization in Walling; M_{PF}=Plastering and Flooring; M_{TP}=Level of mechanization in Tiling and Painting; M_{BS}=Level of mechanization in Building Services

5.0 DISCUSSION OF FINDINGS

5.1 Project Value versus Construction Mechanization

The ANOVA results revealed that project value significantly influences mechanization levels in several categories of construction activities. Specifically, significant differences were observed in site preparation and earthworks (M_{SPE}, $p=.008$), scaffolding and formwork (M_{SF}, $p<.001$), concreting (M_C, $p=.003$), and building services (M_{BS}, $p=.032$). Among these, scaffolding and formwork showed the strongest effect ($F=18.423$), indicating that higher-value projects are far more likely to adopt mechanized scaffolding systems and advanced formwork technologies. Conversely, finishing activities such as walling, plastering/flooring, and tiling/painting did not show significant differences, suggesting that these remain largely manual regardless of project budget. This pattern aligns with global evidence that structural and early-stage works are more readily mechanized in high-budget projects, while finishing works remain labour-intensive due to cost constraints and limited mechanization technologies (Hwang et al., 2020; Pan et al., 2018).

The correlation analysis, however, paints a more nuanced picture. With the exception of concreting ($r = -0.311$, $p=.001$), which showed a moderate negative correlation, all other categories exhibited weak and non-significant relationships with project value. This suggests that while group differences exist (as shown in ANOVA), the overall linear relationship between project value and mechanization is weak.

The negative correlation in concreting is particularly interesting. It implies that higher-value projects may not necessarily mechanize concreting more extensively. Instead, they may rely on specialized subcontractors or advanced manual techniques that achieve quality without heavy mechanization. This contrasts with smaller projects, where mechanization (e.g., mixers, pumps) may be adopted to compensate for limited labour capacity.

These findings resonate with earlier research in both African and global contexts. (Idoro, 2011) found that mechanization in Nigeria's construction industry was concentrated in earthworks and concreting, but adoption was inconsistent across project sizes due to cost and labour market dynamics. (Iheama et al., 2017) similarly observed that mechanization improved efficiency but was often limited to high-value projects, with finishing works remaining manual. (O. J. Adebowale & Agumba, 2023) emphasized that project scale and value are critical determinants of mechanization adoption in Africa, but weak regulatory enforcement and reliance on informal labour markets constrain consistent uptake. (Kulakov et al., 2023) highlighted that digital technologies and lean tools enhance mechanization effectiveness in high-budget projects, but their adoption in developing countries remains limited. In Kenya, (Ndolo et al., 2024) reported that mechanization is most evident in concreting and site preparation, while finishing activities remain manual regardless of project value. Thus, the Kenyan results are consistent with broader literature: project value matters most for structural works, but its influence is uneven and sometimes counterintuitive (as seen in the negative correlation for concreting).

5.2 Project Duration versus Construction Mechanization

The ANOVA results indicate that project duration significantly influences mechanization levels in several categories of construction activities. Significant differences were observed in site preparation and earthworks (M_{SPE}, $p<.001$), scaffolding and formwork (M_{SF}, $p=.002$), concreting

(M_C, $p < .001$), and walling (M_W, p=.009). Among these, concreting showed the strongest effect (F=13.219), suggesting that longer projects are more likely to adopt mechanized concreting methods such as batching plants, pumps, and mixers. Conversely, finishing activities such as plastering/flooring (M_{PF}, p=.298), tiling/painting (M_{TP}, p=.605), and building services (M_{BS}, p=.063) did not show statistically significant differences. This reflects the persistence of manual labour in finishing works, regardless of project duration. These findings align with global evidence that longer projects tend to mechanize structural and early-stage works to achieve efficiency gains over extended timelines, while finishing works remain labour-intensive (Hwang et al., 2020; Pan et al., 2018).

The correlation analysis provides further nuance. Two significant relationships emerged: (i) a Moderate negative correlation in site preparation and earthworks ($r = –0.338$, $p < .001$). Longer projects are associated with lower mechanization in site preparation. This may reflect reliance on phased manual labour or cost-saving strategies in extended projects. (ii) Moderate positive correlation in concreting ($r = 0.247$, $p = .008$). This means that longer projects are more likely to mechanize concreting, consistent with ANOVA findings. For other categories (scaffolding/formwork, walling, plastering/flooring, tiling/painting, building services), correlations were weak and non-significant, indicating that project duration is not a strong linear predictor of mechanization levels in these areas.

These results resonate with earlier research. (Idoro, 2011) found that mechanization adoption in Nigeria was more pronounced in longer projects, particularly in concreting and site preparation, but inconsistently applied in finishing works. (Iheama et al., 2017) observed that project duration influenced mechanization in structural works, but finishing remained manual due to cost and skill limitations. (O. Adebowale & Agumba, 2023) emphasized that project timelines in Africa shape mechanization adoption, with longer projects more likely to integrate machinery for efficiency, though weak regulatory enforcement often undermines consistency. (Kulakov et al., 2023) highlighted that lean and digital technologies enhance mechanization effectiveness in long-duration projects, but adoption in developing countries remains limited. In Kenya, (Ndolo et al., 2024) reported that mechanization is most evident in concreting and site preparation for longer projects, while finishing works remain manual regardless of duration.

These findings align with global and African studies, which emphasize that longer projects mechanize structural tasks for efficiency, while finishing works remain manual. The Kenyan case highlights the persistence of uneven mechanization adoption, shaped by cost constraints, labour market realities, and managerial choices.

6.0 IMPLICATIONS, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Implications

6.1.1 Policy Implications

The findings of this study underscore the critical role of project characteristics, particularly value and duration, in shaping mechanization outcomes in Kenya's construction industry. From a policy perspective, the significant influence of project value on mechanization in structural works (site preparation, scaffolding/formwork, concreting, and building services) suggests the need for targeted incentive frameworks. Government agencies such as the National Construction Authority (NCA) and the Ministry of Infrastructure could introduce tiered subsidies, tax rebates, or import duty waivers to encourage mechanization even in small and medium-value projects, where adoption remains limited. This would help reduce the uneven distribution of mechanization across project categories.

Furthermore, the results highlight the importance of regulatory standards that mandate minimum mechanization thresholds for projects above certain value or duration levels. Such standards would ensure consistency in safety, efficiency, and quality outcomes. Integrating mechanization into Kenya's Vision 2030 and related development frameworks would also align national policy with global trends, where mechanization is recognized as a systemic enabler of productivity and worker welfare.

Finally, the uneven adoption of mechanization across categories, particularly the persistence of manual labour in finishing works, points to a need for capacity building and skills development. National training institutions should incorporate mechanization modules into construction curricula, equipping workers with the technical skills required to operate advanced equipment safely and effectively. This would address the skill gaps that currently constrain mechanization uptake in Kenya.

6.1.2 Practical Implications

At the practical level, the results emphasize the importance of strategic project planning and budgeting. Contractors should recognize that project value and duration are key determinants of mechanization and embed mechanization strategies into project design, particularly for high-value and long-duration projects. This would optimize efficiency, reduce reliance on manual labour, and improve overall project outcomes.

The evidence also points to the need for strategic investment in equipment, with firms prioritizing mechanization in structural works such as concreting, scaffolding, and site preparation, where the strongest impacts were observed. At the same time, contractors should explore affordable mechanization solutions for finishing works, which remain predominantly manual but are critical to project timelines. This hybrid approach would balance productivity gains with labour retention.

Mechanization also has direct implications for safety and quality outcomes. Longer and higher-value projects that adopt mechanized systems are better positioned to reduce accidents and enhance worker welfare. Contractors should therefore view mechanization not only as a tool for efficiency but also as a means of improving occupational health and safety.

Finally, the results highlight opportunities for technology transfer and local innovation. Kenyan firms should collaborate with international suppliers to adapt global mechanization technologies to local contexts, while simultaneously encouraging indigenous innovation to reduce costs and dependency on imports. This would ensure that mechanization adoption is both sustainable and contextually relevant, supporting Kenya's broader industrialization agenda.

6.1 Conclusion

This study set out to investigate the relationship between project characteristics, specifically project value and project duration, and the level of construction mechanization in high-rise building projects in Nairobi. Using survey data from 113 projects and applying ANOVA and correlation analyses, the findings reveal that both project value and duration significantly shape mechanization outcomes, though in different and sometimes uneven ways.

The ANOVA results demonstrated that project value strongly influences mechanization in structural and early-stage works such as site preparation, scaffolding/formwork, concreting, and building services. Larger projects are more likely to adopt mechanized systems, reflecting their greater financial capacity and organizational sophistication. However, finishing works such as walling, plastering, tiling, and painting remain predominantly manual regardless of project value, underscoring the persistence of labour-intensive practices in Kenya's construction industry. Correlation results further revealed that while group differences exist, the overall linear relationship between project value and mechanization is weak, with only concreting showing a significant (but negative) correlation. This suggests that mechanization adoption is shaped not only by financial capacity but also by managerial choices, subcontracting practices, and technical constraints.

Similarly, project duration was found to significantly influence mechanization in structural works, particularly concreting, site preparation, scaffolding/formwork, and walling. Longer projects tend to mechanize these activities to achieve efficiency gains over extended timelines. Yet, correlation results highlighted a nuanced picture: duration was positively associated with mechanization in concreting but negatively associated with site preparation, indicating that extended projects may sometimes rely more on manual labour in preliminary works. As with project value, finishing activities remained largely manual across all durations, reflecting cost limitations and the absence of affordable mechanization technologies in these categories.

Taken together, these findings highlight that mechanization adoption in Kenya's construction industry is uneven and context-dependent. Structural and early-stage works benefit most from mechanization, particularly in high-value and long-duration projects, while finishing works remain manual regardless of project characteristics. This pattern mirrors broader trends in African and global construction, where mechanization is concentrated in capital-intensive tasks but less evident in labour-intensive finishing activities.

The study contributes to the literature by providing empirical evidence from Kenya, demonstrating that project characteristics are critical determinants of mechanization but not sufficient on their own to guarantee widespread adoption. Mechanization outcomes are mediated by managerial decisions, labour market realities, and regulatory environments. These insights carry important implications for policy and practice: policymakers must design incentive frameworks and training programs to encourage mechanization across all project categories, while contractors must strategically plan and invest in mechanization to optimize efficiency, safety, and quality.

Finally, the study acknowledges its limitations, particularly the focus on high-rise projects in Nairobi, which may not fully capture mechanization dynamics in other regions or project types. Future research should expand to include infrastructure projects, rural contexts, and comparative analyses across East Africa. Such studies would enrich understanding of mechanization adoption and provide a stronger evidence base for policy and industry reforms.

6.2 Recommendations

The study makes the following structured recommendations based on various actors;

A. Government and Regulators (NCA, Ministry of Infrastructure)

- **Introduce mechanization incentives:** Provide tax rebates, subsidized leasing, or import duty waivers to encourage mechanization in small and medium-value projects, reducing disparities in adoption.
- **Mandate mechanization standards:** Establish minimum mechanization benchmarks for projects above certain value or duration thresholds to ensure consistency in safety, efficiency, and quality.
- **Integrate mechanization into national policy:** Explicitly recognize mechanization as a productivity driver in Vision 2030 and occupational safety frameworks, aligning national development goals with industry modernization.
- **Support skills development:** Fund training programs and curricula that equip workers with competencies in operating advanced equipment, ensuring mechanization adoption does not outpace workforce readiness.

B. Construction Firms and Contractors

- **Embed mechanization in project planning:** Incorporate mechanization strategies into project design and budgeting, especially for high-value and long-duration projects.
- **Prioritize structural works:** Invest in mechanization for site preparation, scaffolding/formwork, concreting, and building services, where efficiency gains are most evident.
- **Balance labour and technology:** Adopt hybrid approaches that mechanize structural tasks while retaining manual labour in finishing works, safeguarding employment opportunities.
- **Leverage mechanization for safety:** Use mechanized systems to reduce accidents and improve worker welfare, treating mechanization as both a productivity and safety tool.

C. Training Institutions and Academia

- **Curriculum integration:** Incorporate mechanization modules into construction and engineering programs, ensuring graduates are equipped with practical skills for modern sites.
- **Capacity building workshops:** Partner with industry to deliver short courses and certifications on mechanization technologies, targeting site supervisors and artisans.
- **Research and innovation:** Promote applied research on affordable mechanization solutions for finishing works, addressing gaps where manual labour remains dominant.

D. Industry Associations and Professional Bodies

- **Awareness campaigns:** Sensitize members on the benefits of mechanization for productivity, safety, and quality.

- **Standards development:** Collaborate with regulators to develop industry-wide standards for mechanization practices.
- **Knowledge sharing:** Facilitate forums for contractors to exchange experiences on mechanization adoption, challenges, and innovations.

E. International Partners and Technology Suppliers

- **Technology transfer:** Collaborate with Kenyan firms to adapt global mechanization technologies to local contexts.
- **Affordable solutions:** Develop cost-effective mechanization tools suitable for small and medium projects, particularly in finishing works.
- **Capacity partnerships:** Provide training and technical support to ensure safe and effective use of imported mechanization technologies.

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