Enhancing Construction Project Labor Productivity in Kenya

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Abstract

The effectiveness of labor productivity determines whether building projects are successful locally and internationally. It has proven difficult to increase Construction Project Labor Productivity (CPLP) in both developed and developing countries. This has been largely due to lack of standardized metrics, inadequacy of CPLP management models, lack of CPLP improvement frameworks and complexity of the concept. Without the aforementioned, it becomes difficult or impossible for consumers and suppliers to estimate the precise cost of a project, which can cause project stalling, cost escalation, profit loss, and a loss of confidence in the construction sector. This study was a quantitative cross-sectional survey of a sample of 129 ongoing building projects in Nairobi City County. It measures and relates CPLP and its determinants, develops a CPLP predictive model and synthesizes a framework for enhancing CPLP. The study establishes that two attributes, Project Information Flow (PIF) and Project Materials Flow (PMF), account for 83.5% of the variability of CPLP. Finally, it sheds light on the use of the framework for CPLP enhancement. The study concludes that better managing the PIF and PMF may significantly enhance construction project labor productivity.

Keywords: Labor, Productivity, Construction, Flow, Materials, Information

Introduction

The success or failure of a project is determined by its labor productivity (LP). This is especially true for building projects where labor is one of the primary inputs. As much as 65% of the cost of a building project in the construction sector is attributed to labor (Kaja & Jauswal, 2022; Rao *et al.*, 2015). Suffice it to say, labor productivity is the most crucial element influencing the total success of any construction firm, entity or project regardless of size (Jafarifar *et al*., 2020). Thus, to substantially improve construction labor productivity, is to equally enhance both total construction productivity and the general performance in the building project, firm as well as the industry.

Despite the aforementioned acknowledgement, both developed and developing nations grapple with Construction Labor Productivity (CLP) improvement. Since the 1970s, most industrialized nations have seen a decline in the growth rate of labor productivity. The situation has become so adverse that the USA is reported to have experienced average negative growth of -1.2% annually for three (3) decades, from 1977 to 2006 (Sharpe & Fard, 2022; Bahr & Laszig, 2021; Sweis *et al.*, 2008). The middle-income countries are seen to be struggling with CLP improvement challenges (Srikanth *et al.*, 2024; Laghari *et al*., 2021; Razak, 2021; Jalal & Shoar, 2019). The low-income countries, especially the African Continent are noted to be grossly lagging behind with a general incapacity to collect data on all CLP levels except at the national level (Ngoma *et al*., 2024; Lefoka & Windapo, 2023; Bamfo-Agyei *et al*., 2022; Chigara & Moyo, 2022; Adagba *et al*., 2021). All the said countries grapple with similar or near similar challenges with scale being the major difference.

Statement of the Problem

Kenya lacks organized techniques for controlling, enhancing, or assessing labor productivity in construction. Moreover, there are no criteria or standards that are recognized nationally. Lack of performance metrics suggests not knowing one's current position or, more importantly, one's future destination. The problem with the aforementioned is that the "headless chicken" concept is used to operate CLP. The State Department of Labor in Kenya cites the lack of a framework for managing productivity and inadequate research in productivity as some of the causes of poor productivity performance. The country aims to achieve productivity awareness of 60% from an awareness of 1% and to increase productivity by 5% from the current annual improvement of less than 1% (Lukalo & Kiminyei, 2018; GoK, 2013). Research into the development of metrics, methodologies, measurement tools, and enhancement frameworks is crucial to guaranteeing capacity dissemination to the point where every regular contractor understands, can use, and can assess labor productivity as a Key Performance Indicator (KPI).

Research Premise

Through the observation of a limited time frame (thin slice) of the interaction between CPLP and its deciding qualities, a "vital few" determinant factors can be identified, studied, and better managed in order to measure, predict, and enhance CPLP.

Objectives

The objectives of this study were to: (i) determine the level of labor productivity of ongoing projects; (ii) measure the flow of materials and information in ongoing projects as critical determinants of construction project labor productivity (CPLP); (iii) develop a model for predicting construction labor productivity in ongoing construction projects; and (iv) synthesize a framework for improving construction project labor productivity in ongoing construction projects.

Hypothesis

The Research model (Equation 1) is expressed as: -

$$Y = \boldsymbol{\beta}_0 + \sum_{n=1}^{2}(\boldsymbol{\beta}_i x_i) \; +/- \, \epsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:

Y = Construction Project Labor Productivity (CPLP) presented by Project Labor Efficiency (PLE) and Project Labor Cost Competitiveness (PLCC).

$X_{i\,(1,\,2)}$ = Project Critical Workflow Factors (CWFF) ie Information Flow and Materials Flow.

β_0 is a constant

β_1 & β_2 are the regression coefficients (yielding a change in Y for a change in one unit of X_i)

ϵ = error term

The null hypothesis (H_0) therefore was H_0: $\beta_1 = \beta_2 = 0$.

The alternative, (H_a) was H_a: $\beta_i \neq 0$ for at least one single X_i.

Scope of the Study

The scope was evaluated geographically, methodologically and theoretically as described hereafter. The study area was the City County of Nairobi (CCN). CCN was chosen as the study's location for two reasons: first, as Kenya's capital, there is a greater amount of construction activity there than in other parts of the country; and second, limiting the research to a single county minimizes variability. Because the purpose of the study is to determine the nature of the link between the predictor and the criterion variables, it was methodologically designed as a quantitative cross-sectional survey. The study theories were Transformation-Flow-Value (TFV) theory, Theory of Constraints (TOC) and Theory of Thin Slices (TTC).

Literature

Construction Project Labor Productivity

Labor productivity is defined as the amounts produced per hour of work put in by employees, or the ratio of output to input (Sharpe & Fard, 2022). Another way to define it is as the rate of production per unit of time or effort measured and typically represented in labor-hours or man-days (Bahr & Laszig, 2021; AACE, 2004). Examples of such measurements include cubic meters of concrete poured, linear meters of conduit installed, or pipe placed, etc. per crew hour or per man-day. As per these definitions, LP may therefore be expressed mathematically as presented hereafter (Equation 2).

$$Labour\ Productivity\ (LP) = \frac{Output}{Labour\ Cost}\ or\ \frac{Output}{Work\ Hour} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where:

Output is the delivered construction product measure either in monetary terms if several components form the overall output or units of the product if a single output eg m^3 in concrete or m^2 of floor area.

Labor cost is the cost of delivering the output measured in monetary terms or man-hours/man-days.

Work hour is the labor utilized in one hour by one person working on the output.

Man-day is the labor utilized in one day by one person working on the output.

Construction Labor Productivity may be measured at different levels depending on the requirement. According to Pekuri *et al.* (2011), labor productivity can be measured at such levels as the level of the entire economy and industry, highly specialized procedures, or individual employees. At all these levels, construction productivity metrics are necessary due to the intricate structure of the construction process.

This study undertakes labor productivity measurement at the project level. The gross floor area of the project is the output, while the labor input is measured in man-days. CPLP is therefore expressed as Gross Floor Area per Man-Day (GFA per man-Day). Japan, Hong Kong, China, Singapore, Malaysia, and Finland all utilize this measure (Srikanth *et al*., 2024; Chan & Hiap, 2012).

Determinants of Construction Project Labor Productivity (CPLP)

Regarding the elements affecting labor productivity in the construction industry, opinions differ widely. First, the complexity of the building business is mostly to blame for this (Chigara & Moyo, 2022; Lema, 1996). Secondly, the fragmentation of the construction industry means that for the delivery of a project, there are numerous trades involved, each being subject to common challenges but as well having unique challenges that are trade related. Finally, there are dissimilarities in the labor productivity of the countries being studied, construction product, environment, site conditions, geographical location, management features, resources, level of evaluation which may be at national level, industrial level, company level, project level or site level, choice of evaluation method as well as uniqueness of the individual construction worker (Kisi, 2015). All these attributes make it untenable to craft a blanket model.

Despite the aforementioned, construction projects have near similar traits that may be utilized in the creation of an all-inclusive Labor Productivity (LP) management template that can be altered to the individual project peculiarities. Information, materials and components, labor and personnel attributes, equipment and tools, external conditions, pre-requisite works, management, safety, and shared understanding are just a few of the necessary LP determinants for such a proposed template (Ngoma *et al*., 2024; Kisi, 2015; Chigara & Moyo, 2014). Since these elements cooperate to deliver performance, the availability of these resources and factors to the construction project is critical to the success of LP.

To achieve optimal LP, it may not always be necessary to provide an excessive amount of each. Bertelsen *et al.* (2007) states that there is just one important factor that determines how quickly the construction process moves along at any given time. They go on to say that the most important step is identifying the critical determining factor(s). In order to determine their significance in establishing a framework for improving CPLP and in dictating the rate at which optimal LP accomplishment occurs in construction projects, this research investigates the provision of information factors and material and component factors.

Information Factors: Projects are by and large dependent on information for functionality. This data will cover design information as well as communication between the stakeholders and the project team, which is crucial for managing and carrying out the project. The quality, timeliness, completeness, regularity of submission, ease of comprehension, mode of dissemination, availability of information databases, synthesis capacity of information for improvement initiatives, resources availed for information management and availability of feedback channels will to a great extent determine the effectiveness of the information in achieving the construction project goals. All these must be managed in the appropriate manner to reap adequacy of productivity in projects.

Material and Component Factors: Materials are nearly the most critical aspect of any project execution. Pertinent factors in materials will include quantity, quality, sufficiency, timeliness of deliveries, readiness for use, material storage factors, related technology for use, local availability, method of transport to the workface, material site organization practices, supply, material supplier attributes, material procurement management and material reserve sufficiency (Chigara & Moyo, 2022, Naoum *et al*., 2009). Even though all these may not be covered in the model, the most basic for each project must be identified for any project productivity to be attained.

The Development of a CPLP Enhancement Framework

A CPLP enhancement framework and its related procedures must be established in order to effectively manage and improve CPLP. The Collins online dictionary defines a framework as "a particular set of rules, ideas or beliefs which you use in order to deal with problems or decide what to do." Research frameworks are essential for organizing empirical investigations and formulating hypotheses (Partelow, 2023; Ababio & Lu, 2022). The main goal of frameworks is to organize theoretical or conceptual thinking's fundamental concepts into practical models. Their intended purpose is to facilitate the following processes: (i) theoretical fitting; (ii) hypothesizing; (iii) application; and (iv) empirical generalization. Partelow (2023) came to the conclusion that frameworks, in spite of their initial flaws or contentious aspects, are crucial for encouraging scholarly engagement around shared problems. As a result, the first models must be developed in order to address the insufficiency of CPLP frameworks; thereafter, subsequent models will logically follow.

Theoretical framework

Figure 1 shows the interaction of the guiding theories with the variables in the study. The study is guided by three theories: (i) Transformation-Flow-Value (TFV); (ii) Theory of Constraints (TOC): and (iii) Theory of Thin slices (TTS).

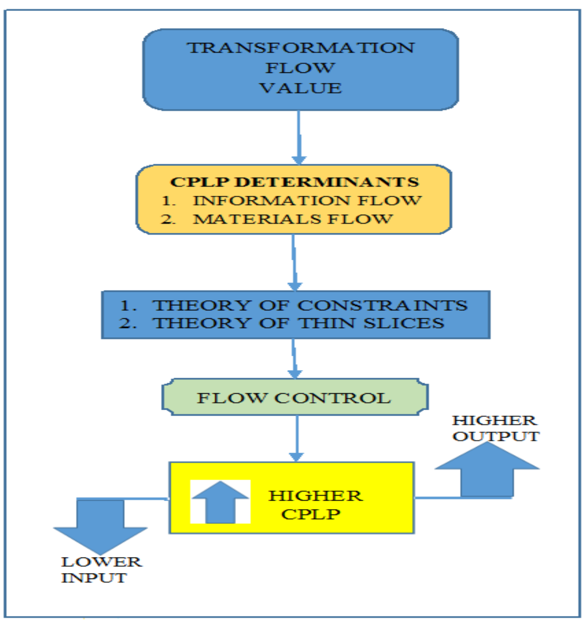

Figure 1: Theoretical Framework
Source: Authors (2024)

TFV establishes the crucial CPLP factors and the nature of their interaction with the construction project. The theory posits that information, materials and components are two (2) of the critical attributes whose flow into a project must be managed for any performance improvement (Mossman, 2015). The theory of Thin Slices (TTS) posits that the study of the interaction of determinant factors of a system over a short duration will enable adequate understanding for prediction (Gladwell, 2005). Finally, the Theory of Constraints (TOC) hypothesizes that improvement goals may be achieved by the removal of a very small number of crucial constraints (Simsit *et al*., 2014). TFV establishes what to study, TTS establishes the nature of undertaking the study while TOC delineates the actions requisite for attainment of the desired outcome. Thus, the interaction of flow of information and materials and components with CPLP will be evaluated over a duration while seeking to understand effect of flow constraints towards optimum CPLP.

Gaps From Literature Review

Literature review established the following gaps: (i) Absence of a CPLP predictive model useable for practical management of CLP in projects; and (ii) deficiency of frameworks for CPLP enhancement in Kenya. A predictive model is essential for monitoring past performance and establishing attainment of future goals while construction is still underway. This allows adjustments to be made in the quest for the necessary improved performance at each stage of the project. The CPLP enhancement framework is crucial for offering a collection of ideas that would serve as a foundation for CPLP management and improvement. The current study believes that in order to support the construction industry's exponential expansion, a workable framework for CLP assessment, management, and data gathering must be established.

Materials and Methods

This research sought to measure the level of CPLP in ongoing building projects, the level of flow of information, and the level of flow of materials and components in ongoing building projects in order to develop a predictive model for CPLP using flow of information and flow of materials and components; and finally, to synthesize a framework for improving labor productivity of ongoing construction projects.

Research Design Strategy

The research was designed as a cross-sectional survey targeting ongoing projects within Nairobi City County with the sampling frame being a list of projects approved for construction between 2021 and 2023. The sampling unit was also the observation unit which was a project. The sample was housing projects with a maximum project value of not more than 300 million Kenyan Shillings (< Kshs. 300million). The sample size was determined by the Yamane formula (Kothari & Gang, 2014). A total of 180 projects were selected for the sample using simple random sampling. Senior project staff were given a questionnaire to complete in order to collect data. 129 questionnaires were found to be responsive during data collection, representing a 71.6% response rate. Kothari (2004) affirms that a response rate of at least 30% is appropriate. Regression analysis and descriptive statistics were used in the data analysis process. These analyses were carried out using Microsoft Excel and IBM® SPSS® Statistics v25.

Variables in the Study

The criterion variable was Construction Project Labor Productivity (CPLP) measurable through two (2) attributes: Project Labor Efficiency (PLE) and Project Labor Cost Competitiveness (PLCC). The Project Labor Efficiency (PLE) was accordingly calculated using Equation 3 in five (5) steps; (i) the value of work undertaken in that given month was established, (ii) the proportion of the project executed in that particular month was estimated by dividing the value of work by the total contract sum, (iii) the proportionate plinth area executed in that month was calculated by the proportion of the project executed by the total plinth area, (iv) establishing the total monthly labor in man-days, and lastly (v) dividing the proportionate plinth area executed in that month by the total monthly labor in man-days.

$$\text{PLE} = \left(\frac{\text{Monthly value of work (Kshs.)}}{\text{Total contract sum (Kshs)}}\ \text{X}\ \frac{\text{Total Project Plinth Area (m}^2\text{)}}{\text{Monthly labor (man-days)}}\right) \ldots\ldots\ldots\ldots\ldots (3)$$

The Project Labor Cost Competitiveness (PLCC) was calculated using Equation 4 in four steps; (i) the labor payments per day were determined, (ii) the monthly labor payments were calculated by multiplying the total daily payments by the number of days the employees had worked, (iii) the value of work undertaken in that month was determined, and lastly (iv) the project labor cost competitiveness was estimated by dividing the value of construction output by the total monthly labor cost ; both measured in Kenya Shillings (Kshs) revealing a ratio.

$$\text{PLCC} = \frac{\text{Monthly value of work undertaken (Kshs.)}}{\text{Monthly Labor Cost (Kshs.)}} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The two (2) Productivity measures were harmonized into Construction Project Labor Productivity Index (Equation 5):

$$PCLPI_i = \frac{1}{2}\left[\frac{PLE_i}{PLE_{mdn}} + \frac{PLCC_i}{PLCC_{mdn}}\right] \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where:

$CPLPI_i$ = Construction Project Labor Productivity Index for the i^{th} observation
PLE_i=Project Labor Efficiency for the i^{th} observation
$PLCC_i$=Project Labor Cost Competitiveness for the i^{th} observation
PLE_{mdn} = The median Project Labor Efficiency for the number of observations
$PLCC_{mdn}$=The median Project Labor Cost Competitiveness from the observations

The predictor variable was Critical Workflow Factors (CWFF) represented by two (2) surrogates: (i) Project Information Flow (PIF) and (ii) Project Materials Flow (PMF). PIF was measured using five (5) attributes while PMF was measured using eleven (11) attributes. Each of the attributes was rated on a six (6) point Likert scale and summated to a total score for both surrogates of CWFF.

Reliability and Validity

Cronbach's Alpha (α) was used to assess the internal consistency of the questionnaire. A reliability coefficient of 0.60 is deemed low on the Cronbach's Alpha scale, 0.7 is deemed acceptable, and more than 0.80 is deemed good. With a Cronbach's Alpha of 0.901, the questionnaire demonstrated a good degree of internal consistency. Construct validity was used in the study to evaluate how well the operational definitions and measurements used in the investigation reflected the theoretical constructs or concepts under investigation. This was crucial to ensure that the study's objectives were met by the variables and measurements that were employed.

Results And Discussion of Findings

Critical Workflow Factors (CWFF)

The flow of CWFF (information flow and materials and components flow) parameters were calculated as a percentage (Equation 6) using the Relative Importance Index (RII) with each attribute rated on six-point Likert scale which ranged from 1 (never) to 6 (always).

$$RII\ (\%) = \frac{6n6+\ 5n5+4n4+3n3+2n2+1n1}{6(n6+n5+n4+n3+n2+n1)} * 100 \ldots\ldots (6)$$

Where:
n1, n2, n3, n4, n5 and n6, = the number of respondents who selected:
n is the weighting given to each factor by the respondents (ranging from 1 to 6).

Flow of Information

The results have been presented on Table 1. The highest and lowest ranking factors based on mean score were ‘Timeliness of information provision when required’ and ‘request for additional information’ with means of 4.38 and 2.93 respectively. The highest attribute in terms of Relative Importance Index (RII) was “Information resources on site” at 67.79% while the lowest was “Request for additional information” with RII of 48.28%. The standard deviation for overall flow of information was 0.81 indicating that the Flow of Information had high disparities in performance between projects.

Table 1: Flow of Project Information.

Attributes	Code	N	Mean	Std. Dev.	RII	Rank
Information resources on site	IF01	129	4.07	1.52	67.79%	1
Request for additional design details	IF02	129	3.35	1.43	64.32%	2
Extent of variations	IF03	129	3.49	1.52	60.93%	3
Timeliness of information provision when required	IF04	129	4.38	1.50	53.33%	4
Request for additional information	IF05	129	2.93	1.56	48.28%	5
Overall Flow of Information		129	3.65	0.81	58.04%	

Source: Authors (2024).

The RII score of the flow represents the level of reliability or certainty of the flow – the percentage likelihood that the particular flow will be available in the correct quantity and in the requisite quality at the required time. The Flow of Information had an average Flow reliability of 58.04% based on the five factors of PIF. Figure 2 presents the comparison of the Flow Certainty of the five Information attributes. The Flow Certainty of “Request for additional information” was generally low and below average.

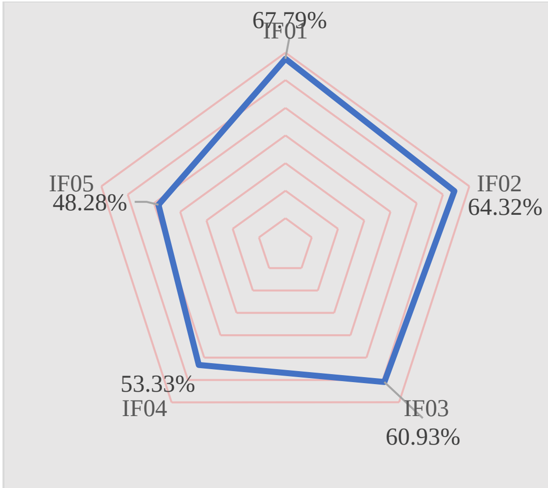

Figure 2: Flow Certainty of Information Attributes
Source: Authors (2024)

Flow of Materials

The results of the scores of Flow of Materials have been presented on Table 2. The two best performing PMF attributes were found to be 'availability of correct standard/quality of materials on site' and 'availability of the correct type of materials on site' with means of 3.94 and 3.91 respectively. The two least performing material factors were found to be 'Suppliers are chosen based on best prices of quotation.' and 'Suppliers are paid on time as expected.' with means of 3.16 and 3.23 respectively. An overall mean of 3.42 indicates that performance on the flow of material attributes was just slightly above average. Based on the RII score, 'Suppliers are chosen based on best prices of quotation' was the highest at 65.57% and the lowest was 'Suppliers provide the materials on time as expected' at 56.98%'. The standard deviation for the overall flow of materials was 0.36 indicating that the material-related attributes had a minimal spread between the average of the lowest attribute and the average of the highest attribute.

Table 2: Flow of Materials Attributes

Attributes	CODE	N	Mean	Std. Dev.	RII	Rank
Suppliers are chosen based on the best prices of quotation.	MF01	129	3.16	1.29	67.57%	1
The same regular suppliers are used.	MF02	129	3.43	1.49	65.63%	2
Availability of the correct sequence/harmony of material on site	MF03	129	3.52	1.38	65.37%	3
Availability of correct type of materials on site	MF04	129	3.91	1.41	64.60%	4
Availability of easy access of materials at the work area on site	MF05	129	3.57	1.52	63.44%	5
Availability of the correct standard/quality of materials on site	MF06	129	3.94	1.35	63.31%	6
Availability of the correct quantities of material on site	MF07	129	3.58	1.52	61.89%	7
Suppliers are paid on time as expected.	MF08	129	3.23	1.55	61.50%	8
Suppliers are changed based on need.	MF09	129	3.37	1.46	61.11%	9
Availability of the correct organization of materials on site	MF10	129	3.42	1.53	59.17%	10
Suppliers provide the materials on time as expected.	MF11	129	3.67	1.54	56.98%	11
Overall Flow of Materials		129	3.42	0.36	62.28%	

Source: Authors (2024)

The RII score of the flow represents the level of reliability or certainty of the flow of materials attributes – the percentage likelihood that the particular flow will be available in the correct quantity and in the requisite quality at the required time. The flow certainty of project materials increased with increasing RII value. The Average Flow of Materials was 62.28% based on the eleven (11) attributes of project materials flow. Figure 3 presents the general performance of the Flow Certainty of the Materials attributes. The Flow Certainty of “Availability of the correct organization of materials on site” and “Suppliers provide the materials on time as expected” was low as compared to the other attributes.

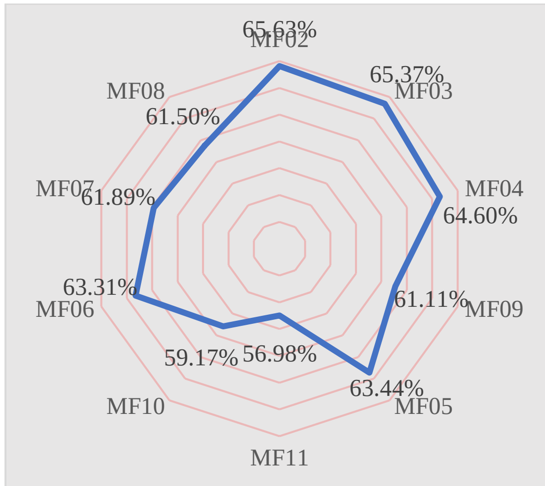

Figure 3: Flow Certainty of materials.
Source: Authors (2024)

Construction Project Labor Productivity (CPLP)

The results for PLE, PLCC and CPLPI are presented in Table 3 and discussed thereafter.

Table 3: Construction Project Labor Productivity (CPLP)

Factor	N	Min	Max	Mean	Std. Dev.
Project Labor Efficiency (PLE) - m^2/man-day	129	0.02	0.29	0.14	0.06
Project Labor Cost Competitiveness (PLCC)	129	1.18	9.83	5.34	2.12
Construction Project Labor Productivity Index (CPLPI)	129	0.20	1.72	0.99	0.38

Source: Authors (2024)

The values for PLE ranged from 0.02m^2/man-day to 0.29m^2/man-day with a mean of 0.14m^2/man-day and a standard deviation of 0.06 m^2/man-day. The coefficient of variation was 42.86%. PLCC had a mean of 5.34 and a standard deviation of 2.12 and coefficient of variation of 39.7%. The values varied from a low of 1.18 to and a high of 9.83. The standard deviation for both indicates that the data was routinely spread out, without being in either of the extremes. The spread for PLE was higher than that for PLCC.

The PLCC average of 5.34 indicates that an expenditure on labor realized 5.34 times the value in construction output. On the other hand, the reciprocal of PLCC is the fraction of the quantity of construction output that was spent on labor. The reciprocal of the obtained average PLCC of 5.34 is 0.187 indicating that the labor component was 18.7% of the value of the total construction output. The lowest PLCC value (1.08) yields a reciprocal of 0.847 indicating that the labor cost was 84.7% of the monthly construction output. The highest PLCC value (9.83) yielded a reciprocal of 0.102 indicating that the labor cost was 10.2% of the monthly construction output value.

CPLPI had a mean very close to unity (0.99). The coefficient of variation was 38.25%. The least CPLPI was 0.20 and the highest 1.72. The range between the highest and the least was 1.52 indicating that the project with the lowest CPLPI delivered 12% of the CPLP of the project with the highest CPLP. In as much as it may be expected that there will be super-achievers and under-achievers in a sample of projects, this disparity is high. This is a pointer to among other things, a gross difference in training or labor productivity awareness, scale or size as well as adverse discrepancy in the level of mechanization between the projects (Mossman, 2015). On the other hand, the standard deviation of 0.38 indicated an average spread of values.

Regression Analysis

Multiple Regression analysis was undertaken utilizing CWFF (Flow of Information and Flow of Materials) as the regressor and CPLPI as the regressand. The outcome of the regression analysis is presented on Tables 4, 5 and 6 hereafter.

Table 4: Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.914[a]	0.835	0.832	0.156
[a] Predictors: (Constant), Information Flow, Materials Flow.				

Source: Authors (2024)

Table 5: Coefficient Results

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		β	Std. Error	Beta		
1	(Constant)	-0.004	0.051		-0.072	0.943
	Information Flow	0.05	0.022	0.132	2.295	0.023
	Materials Flow	0.232	0.016	0.808	14.095	0.000
[a] Dependent Variable: Construction Project Labor Productivity Index						

Source: Authors (2024)

Table 6: Analysis of Variance (ANOVAa).

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	15.535	2	7.767	318.822	0.000[b]
	Residual	3.07	126	0.024		
	Total	18.605	128			
[a] Dependent Variable: Construction Project Labor Productivity Index						
[b] Predictors: (Constant), Information Flow, Materials Flow						

Source: Authors (2024)

The β coefficient on Table 5 indicates the amount of the change in the criterion variable (CPLPI) that results from a unit change in the predictor variable. For Project Information Flow (PIF), there was a positive and significant ($p<0.023$) association with CPLP. The regression coefficients intimated that a 5% increase in

CPLPI would result from a unit increase in PIF. Project Materials Flow (PMF) equally indicated a positive and significant (p<0.001) association with CPLP. The regression coefficients indicated that a 23.2% increase in CPLPI would result from a unit increase in PMF.

Predictive Model for Construction Project Labor Productivity (CPLP)

The study's objective was to create a predictive model that would evaluate how CWFF affects CPLP of building projects in Nairobi by measuring the flow of information and project materials. In order to accomplish the aforementioned goal, a statistical model was created. The estimated model is given as Equation 7.

CPLPI = - 0.004 + 0.05PIF + 0.232PMF +/- 0.156 ………………………………. (7)

Where
CPLPI = Construction Project Labor Productivity Index
PIF = Project Information Flow
PMF = Project Materials Flow

The value of R^2 (0.835) on Table 4 represents the coefficient of determination. It indicates the degree to which variability in CPLPI is explained by the model. In this case, 83.5% of the variability in the CPLPI is explained by the model, at a confidence level of 99.99% (P<0.0001). The *regression constant* of -0.004 (Table 5) is not statistically significant (p<0.943), while the *Sum of Squares Regression* (Table 6) is statistically significant (P<0.0001). It means that the constant value of CPLPI (-0.004) on the model may be accurate only 5.7% of the time while the value of CPLPI obtained from the regression model calculation will be accurate 99.99% of the time. These two results imply that the regression model is well specified. The regression equation above is therefore accurate and can be used to make credible predictions on CPLP.

Significance was measured using the F-test statistic. The ANOVA generated from the regression analysis established that the model was significant F (2, 128) = 318.822, p<0.001. Flow of information and Flow of materials were confirmed as significant attributes in predicting CPLP. If the resulting figure of the F-statistic is high, then the random error is tending towards zero and thus the similarity between the outcome of populating the model with any random members from the same population is 99.99% (Hair *et.al*, 2014). The model may therefore be generalised to the entire population.

A Framework for Improvement of CPLP

The predicted scores for Project Information Flow (PIF) and Project Materials Flow (PMF) may be calculated using constraint analysis (Equation 8) from the attributes on Table 1 and 2 respectively.

$$Predicted\ PIF/PMF = \frac{10 - No.of\ identified\ constraints}{10}$$ ………………... (8)

A baseline value of the best achievable CPLP is required as the target CPLP. This may be obtained either by benchmarking other projects or obtaining the CPLP for the most flawless performance over a 5-day period within the project. This baseline value becomes the target that the improvement framework requires to match or surpass. Assuming the predicted CPLP value for the upcoming duration matches the baseline (which is the condition for progress of work), then (CPLP ÷ (baseline CPLP)) is equivalent to Unity (1.0). Upon substituting the predicted CPLP with the aforementioned numerical equivalent and upon removing the constant (-0.004) and the error term (+/- 0.156), the predictive model (Equation 7) is transformed to Equation 9.

$$0.05PIF + 0.232PMF = 1.0 \quad (9)$$

Multiplying by 1000 results in Equation 11.

$$5PIF + 232PMF = 1000 \quad (10)$$

To predict CPLP performance for any upcoming construction duration compared to the baseline value, Equation 10 is used upon solving for the summated and weighted PIF and PMF projections using the baseline values. Equation 11 is the statistical expression of the CPLP enhancement framework.

$$CPLP' = \frac{1}{1000}[5PIF' + 232PMF'] \quad (11)$$

The satisfactory condition for project execution to proceed is $CPLP' \geq CPLP$

Where:

CPLP in the above satisfactory condition is Baseline CPLP from database
CPLP′ = Predicted CPLP
PIF′ = Projected PIF (upon weighting using baseline PIF value)
PMF′ =Projected PMF (upon weighting using baseline PMF value)
PIF = Project Information Flow
PMF = Project Materials Flow

Discussion of Findings.

The Construction Project Labor Productivity (CPLP) was measured directly from the project using CPLP index, a concept developed using Project Labor Efficiency (measured in m^2 per man-day) and Project Labor Cost Competitiveness (a ratio of construction output to equivalent labor cost). The Flow of project information and flow of project materials were measured through a perception survey of senior project personnel.

Level of Critical Workflow Factors; Flow of Information and Flow of Materials.

The study achieved the objective of measuring the determinants of CPLP. The Certainty of Flow of Materials was 62.28% while the certainty of Flow of Information was 58.04%. Both values were slightly above average. This level of performance is low compared to global standards (Mossman, 2015) and therefore likely to yield underwhelming levels of CPLP.

Level of Construction Project Labor Productivity (CPLP).

The objective of measuring CPLP was achieved. This was attained by using CPLP index developed from combining two (2) surrogates; Project Labor Efficiency (PLE) and Project Labor Cost Competitiveness (PLCC). The average score of CPLP for the sampled projects was PLE of $0.14m^2$ per man-day, PLCC of 5.34 (labor is 18.7% of project output value) and CPLPI of 0.99.

The average PLE at 0.85m^2/man-day in Finland was 6.07 times the average PLE in Kenya for the projects sampled while the average PLE in Japan and Singapore at 0.4m^2/man-day was more than twice the Kenyan average (Building Construction Authority, 2016). The mean PLCC of Kenya at 5.34 (labor is 18.7% of the project output value) was 160% that of Egypt at 3.33 (labor is 30% of project output value) meaning that Kenya is 60% more competitive at labor cost competitiveness than Egypt (Khaled & Remon, 2020). Despite outperforming Egypt in PLCC, Kenya is yet to attain globally competitiveness in CPLP.

The Development of a CPLP Predictive Model.

The predictive model was revealed as: CPLPI = - 0.004 + 0.05PIF + 0.232PMF +/- 0.156

Upon testing the hypothesis (Equation 1): the Null Hypothesis, Ho: $\beta_1 = \beta_2 = 0$ was rejected and the Alternative Hypothesis H_a: $\beta_i \neq 0$ for at least one X_i was confirmed. According to the study, Flow of Materials ($p<0.001$) and Flow of Information ($p<0.023$) were significant in predicting CPLP. Thus, project information flow and project material flow may be used to measure, forecast, and control the CPLP management system. Moreover, to fully profit in the enhancement of CPLP, project practitioners need to enhance information and material flow management during project execution.

The Synthesis of a Framework for Enhancing CPLP.

A CPLP enhancement framework was synthesized and presented in the form of a statistical equation: $\boldsymbol{CPLP}' = \frac{1}{1000}[5\text{PIF}' + 232\text{PMF}']$; proceed only if CPLP′≥CPLP

Firstly, a process of improving CPLP requires to undertake CPLP prediction evaluation for proposed scheduled works through constraint analysis. Secondly, work may not proceed until the anticipated CPLP is equal to or greater than the baseline CPLP. Based on the statistical predictive model and improvement framework, it is possible to develop a CPLP mobile phone management application to ease such tasks as constraint analysis, prediction based on current project conditions, provision of feedback for potential performance enhancement alternatives, and determination of attainment of requirements for going ahead with planned activities. Moreover, field testing of the framework is proposed as an immediate area for future research.

Recommendations

The recommendations that follow are derived from the study's results and conclusions:

- To raise industry awareness of CPLP, mandatory self-reporting of CPLP performance in construction projects ought to be a major focus.
- CPLP should be adopted as KPI in evaluation of performance of construction companies and projects.
- Training and re-training of potential, new and existing construction workers to ensure CPLP is "culturised" in the management of projects within the Kenyan construction sector.
- A more proactive, structured and thorough management of CPLP is critical - adoption of the CPLP improvement framework for construction projects is proposed.

Authors Declaration of Conflict of Interest.

Regarding this paper, the authors desire to disclose that they have no potential conflicts of interest.

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