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Propuesta de modelo matemático para calcular el rendimiento de mano de obra en mampostería de bloque. Caso: ciudad de Cuenca, parroquia Cañaribamba

Proposal of a mathematical model to calculate the performance of work command in block masonry. case: Cuenca city, Cañaribamba Parish

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Palabras claves: Rendimiento, regresión lineal, mano de obra, mampostería.

Resumen

Introducción. La colocación de la mampostería de bloque emerge como una fase crítica en el proceso constructivo, donde la eficiencia y precisión influyen directamente en la duración y calidad del proyecto. Esta actividad, aunque aparentemente simple, conlleva una complejidad inherente que a menudo resulta en retrasos significativos en la ejecución de la obra. La necesidad de comprender y abordar los factores que contribuyen a estos retrasos es evidente, ya que su impacto no solo se refleja en términos de cronograma y presupuesto, sino también en la satisfacción del cliente. **Objetivo.** Proponer un modelo matemático para calcular el rendimiento de la mano de obra en la colocación de mampostería con bloques en la Parroquia Cañaribamba, Cuenca, Ecuador. **Metodología.** El diseño metodológico adoptado sigue una orientación relacional y descriptiva, involucrando la recopilación de datos de nueve obras mediante una ficha de observación que abarca tanto factores externos como internos. Utilizando estos datos, se llevó a cabo un análisis de regresión lineal mediante un programa estadístico. **Resultados.** Los resultados destacan que, individualmente, ningún factor analizado influye significativamente en el rendimiento laboral; sin embargo, la combinación de estos factores permite prever el rendimiento con una precisión del 93.3%. **Conclusión.** Se concluye que la regresión lineal emerge como una herramienta robusta para anticipar el rendimiento de cuadrillas de obreros en la Parroquia Cañaribamba, considerando la complejidad de factores tanto internos como externos en las obras. **Área de estudio general:** Ingeniería, Industria y Construcción **Área de estudio específica:** Administración de la Construcción

Keywords: Performance, linear regression, labor, masonry.

Abstract

Introduction. The placement of block masonry emerges as a critical phase in the construction process, where efficiency and accuracy directly influence the duration and quality of the project. This activity, although seemingly simple, carries an inherent complexity that often results in significant delays in the execution of the work. The need to understand and address the factors contributing to these delays is evident, as their impact is not only reflected in terms of schedule and budget, but also in customer satisfaction. objective. To

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propose a mathematical model to calculate the labor performance in the placement of masonry with blocks in Cañaribamba Parish, Cuenca, Ecuador. Methodology. The methodological design adopted follows a relational and descriptive orientation, involving the collection of data from nine construction sites by means of an observation sheet that covers both external and internal factors. Using these data, a linear regression analysis was carried out using a statistical program. Results. The results highlight that, individually, none of the factors analyzed significantly influences job performance; However, the combination of these factors allows predicting performance with an accuracy of 93.3%. Conclusion. It is concluded that linear regression emerges as a robust tool to anticipate the performance of work crews in the Cañaribamba Parish, considering the complexity of both internal and external factors in the works.

Introduction

Nowadays, increasing competition and increasingly stringent quality demands from consumers have driven a significant evolution in construction project management (Jeremiah et al., 2019). This development goes beyond simply achieving high-quality execution; in the modern era, resource optimization has become a priority for managers and administrators in order to generate value while mitigating potential losses in key areas such as time, financing, and planning in the construction industry (Atencio et al., 2022).

From this perspective, among the essential tools available to construction managers and administrators for planning and estimating operating costs is the calculation of labor performance. This factor is established as a key determinant to achieve effective managerial results. Likewise, an accurate anticipation of labor performance is of utmost importance, since its incorrect application can lead to unfavorable consequences in terms of planning, budget, quality control and customer satisfaction (Ouyang et al., 2022).

In the same vein, in the construction industry, there are several activities that can be considered as: Critical Activities (CA), that is, those that have the potential to generate major delays in construction if they are not properly planned and executed by efficient personnel (Yap et al., 2021). Among these CA is the placement of block masonry, which can significantly affect execution times if not properly planned (Xu et al., 2021). In the given scenario, some important questions arise: What are the factors that have a

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detrimental impact on the job performance of those involved in the placement of block masonry? and Is it possible to predict the performance of the workforce in the block masonry placement activity through a mathematical model?

The main objective of this study is to propose a mathematical model based on Linear Regression (LR), through the application of data collection instruments in different works in the city of Cuenca to identify the factors that directly influence the performance of the workforce. The importance of achieving this objective lies in its contribution to comprehensive knowledge within the field of construction, particularly with regard to the factors that decisively influence the performance of the workforce dedicated to the placement of blocks in the city of Cuenca.

In this context, the use of a predictive tool that incorporates the above criteria will lead to better resource planning and greater accuracy in projecting project completion times. The potential to predict work performance using these features provides managers with the opportunity to refine their strategies more accurately, thereby reducing potential delays and maximizing the allocation of people and material resources. That is, achieving the objective set out in this research will not only improve the progression of knowledge within the construction sector, it will also provide managers with a valuable tool for making well-informed decisions and formulating strategic plans, thereby maximizing results.

This research was carried out in the city of Cuenca, specifically in the Cañaribamba Parish, a sector that has the ideal conditions for the fulfillment of the objectives of this research since it is considered a center of continuous urban expansion and has several construction projects in progress that include the placement of block masonry as a central axis in most projects.

The research is carried out in the context of nine different architectural projects in the Cañaribamba Parish where the initial stages of block masonry installation are being carried out. The aforementioned projects were chosen because they are located in the study area in the masonry placement phase. The research methodology used in this study is a combination of relational and descriptive lines with a quantitative approach, incorporating statistical analysis and linear regression techniques. This approach allowed identifying trends between crucial variables and developing prediction models and recommendations aimed at standardizing and improving efficiency in construction projects.

The Dependent Variable (DV) of this research is the Labor Efficiency (LFE) that can be conceptualized as the volume of work per unit of time (m2/hour) obtained by collecting data from both workers and government sources. On the other hand, the Independent Variables (IV) of this research are the factors that can influence the LFE and were determined from the research of Cano and Duque (2000) such as: climate, type of activity, equipment, supervision and worker's own conditions. The data for the definition of the IV will be determined through observation sheets. The analysis of the interaction between these variables will provide information on the results of the placement of masonry blocks in terms of performance.

Within the framework of the above, the present research aims to calculate the standard performance in the placement of block masonry. For this, correlation analyses were carried out and the linear regression method was used to predict or estimate said performance based on different factors or explanatory variables. The aim was to provide a tool that helps to evaluate the probability of achieving high performance in workers based on the independent variables that affect the labor performance of the placement of block masonry.

Below is the theoretical reference material used to prepare this document that allowed the variables under study to be characterized:

Labor performance

RMO refers to the ability of a worker or team to complete tasks in a specific period of time. This measure, often expressed in terms of output per hour, day, or week, serves as a basic assessment of the workforce's effectiveness and productivity. This indicator is more than just a number; it is critical for evaluating performance and improving work processes. By quantifying the relationship between work completed and time spent, companies can identify areas of strength and opportunities for optimization. This improves resource management and results in better work outputs (Cock et al., 2022).

As mentioned, calculating RMO is important in construction for several reasons. The first advantage is that it allows project managers to predict how much work they can complete in a given time period, making project planning and scheduling easier. Second, by using RMO calculation to identify bottlenecks and problem points in the construction process, managers can take steps to increase productivity and efficiency. Third, RMO calculation can help managers set achievable goals for the work team, increasing employee engagement and motivation (Bartoschek and Kamenov, 2021).

Understanding the various factors that influence construction RMO is of significant importance as it enables project managers to effectively recognize and resolve any concerns that may be impeding worker productivity. Through a comprehensive understanding of the various factors that exert influence on labor productivity, project managers are empowered to implement measures aimed at improving worker efficiency. This, in turn, has the potential to result in cost reduction and elevation of the overall quality of work. Furthermore, improving RMO can lead to increased competitive advantage for the company within the market and elevation of customer satisfaction (Hamza et al., 2022).

But how do we know which factors influence the RMO? To answer this question, we can use some methods to identify the influencing factors available. In this research, we use the criteria provided by Cano and Duque (2000), who mention in their research that the aforementioned factors can be determined through 7 categories, which are:

1. In the field of economics, there are various factors that influence productivity. These factors include inflation, interest rates, availability of materials and market competition. 2. Work dimensions: elements related to working conditions, covering aspects such as remuneration, social security, training and motivation. 3. Climate refers to the set of environmental elements that can affect the performance of workers, covering factors such as temperature, humidity, rainfall and solar radiation. 4. Activity: Factors related to the activity to be carried out, including the level of difficulty, complexity, duration and interconnection with other activities. 5. Equipment: Factors related to the equipment and tools used, covering aspects such as quality, condition, sufficiency, maintenance and accessibility. 6. Supervision: This criterion covers various factors associated with the supervision and guidance provided to people in their work, including the quality, quantity, timeliness and effectiveness of supervision. 7. Factors pertaining to the worker cover various aspects, including their experience, skill level, health status, motivation and attitude.

Linear regression

RL is a statistical methodology used to establish a mathematical model that represents the association between a DV and one or more IVs. The purpose of this method is to make predictions about the value of the DV using the values of the IVs. RL is based on the assumption that there is a linear association between the variables, which implies that alterations in the IVs are accompanied by proportional modifications in the DV. The objective of RL is to identify the optimal regression line that minimizes the difference between the observed values and the predicted values. The best-fit line is determined by applying the least squares method, which aims to minimize the sum of the squared differences between the observed values and the predicted values (Maulud and Mohsin, 2020).

Using RL is a competent approach to assess the correlation between a DV, such as labor productivity, and multiple independent variables, such as factors influencing labor productivity. Using multiple regression analysis allows for assessing the impact of individual IVs on DV, while taking into account the potential influence of other independent variables. Standardized regression coefficients are used to determine the degree of influence each factor exerts on labor productivity (Hai and Tam, 2019).

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RL enables managers to make predictions about future accuracy values by creating a model of the relationship between variables. The importance of this lies in its ability to enable organizations to make well-informed decisions regarding improving their managerial effectiveness. For example, in the case where linear regression analysis indicates a significant association between project delivery accuracy and goal management, an organization can implement measures to improve its goal management procedures, which will consequently lead to an improvement in the accuracy of its goal delivery (Gata et al., 2019).

Methodology

Design

This research follows a methodological design framed in the relational-descriptive line of research that focuses on establishing patterns between key variables that affect the performance of the workforce in the placement of block masonry. This was developed through statistical analysis based on linear regression, where predictive models and recommendations could be established for the prediction of the possible performance that can be obtained from the workers and the improvement of efficiency in this area. There are two approaches to the problem: The first; is the descriptive analysis through which the causes or factors that affect the real performance of block masonry and the possible situations that enhance them are studied. The second; is the relational analysis, object of study of this work, whose purpose is to analyze the correlation between the VI and its indicators.

The methodological approach used is quantitative, since the data to be collected from the works, as well as their subsequent analysis, will be carried out through a statistical information program that allowed obtaining numerical relationships between the variables. This research uses 4 methodological stages that are mentioned below:

Definition of variables

In order to collect data, it is important to begin by operationalizing the study variables, in order to define specifically what is intended to be measured and how these measurements are planned to be carried out. In the specific case of this research, a DV, which is the RMO, is measured through different IVs identified in the theoretical referencing and their indicators, which are represented with a numerical transposition (equivalent values from 1-5) that are presented below in Table 1.

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Table 1

Operationalization of variables

VI	Indicators	1	2	3	4	5
Climate	Time	Storm	Downpour	Drizzle	Cloudy	Clear
Climate	Temperature	Very Hot/VeryCold	N/A	Hot/Cold	N/A	Cool
Activity	Floor	Swampy	Puddles	Wet floor	Dry floor	Hard floor
Activity	Deck	Sun	N/A	Normal	N/A	Shade
Activity	Difficulty	Difficult	N/A	Normal	N/A	Easy
Activity	Danger	Dangerous	Risky	Normal	Moderate	No danger
Activity	Interruptions	≥ 1 hour	15≥60 min	5≥15 min	0≥5 min	None
Activity	Order and cleanliness	Difficult access	Rubbish	Passable	Little dirt	Total cleanliness and order
Activity	Previous activities	Repeat	A lot of healing	Little healing	Acceptable	Perfect
Activity	Typicality	From 1 to 5	From 5 to 10	From 10 to 15	From 15 to 20	More than 20
Equipment	Tajo (Workspace)	Very narrow	Narrow	Normal	Broad	Very spacious
Equipment	Tool	Inadequate	N/A	Adequate	N/A	Special
Equipment	Equipment	Inadequate	N/A	Adequate	N/A	Special
Equipment	Maintenance	Null	N/A	Acceptable	N/A	Well
Equipment	Supply	Never	N/A	Sometimes	N/A	Always
Equipment	Protective element	None	N/A	Almost all	N/A	All

Table 1

Operationalization of variables (continued)

VI	Indicators	1	2	3	4	5
Cli	Time	Storm	Downpour	Drizzle	Cloudy	Clear
Cli	Temperature	Very Hot/VeryCold	N/A	Hot/Cold	N/A	Cool
Supervision	Address (acceptance criteria)	None	Informal	Verbal	Previous verbals	Under written
Supervision	Instruction	None	N/A	Verbal - required	N/A	Required document
Supervision	Follow-up	No review	N/A	Eventual review	N/A	Always
Supervision	Supervisor (Teacher)	Bad	N/A	Regular	N/A	Well
Supervision	Quality Assurance	It does not exist	Isolated efforts	Inventory	In progress	ISO Certificate
W	Personal situation	Neurotic	Sad	Normal	Good	Excellent

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Labor	Work pace	Slow	N/A	Normal	N/A	Fast
	Health	Sick	N/A	Normal	N/A	Excellent
	Ability	Inexperienced	N/A	Skilled	N/A	Expert
	Training	None	Apprentice	Required	Expert	Certificate
	Contract	Administration	N/A	N/A	N/A	Outsourcing
	Union	Yeah	N/A	N/A	N/A	No
	Incentives	No	N/A	N/A	N/A	Yeah
	Salary	SMLV	N/A	N/A	N/A	≥SMLV
	Social security	Yeah	N/A	N/A	N/A	No

*Note.*Adapted from Cano and Duque (2000)

Prepared by: Authors

Data collection form design

An observation form was created and applied to nine different projects, which allowed for the collection of information on the variables identified in the operationalization of the variables. The observation form consisted of 26 response options that are aligned with the indicators of each VI.

Definition of universe and sample

The study universe of this research focuses on architectural projects in the masonry placement phase in Cuenca, Ecuador, with the target population consisting of the 21 constructions in progress located in the Cañaribamba parish. The sample was determined by applying the convenience sampling technique, which involves the non-random selection of elements based on the accessibility and convenience of the researcher, as opposed to a more rigorous random selection method (Hernández, 2021). In this context, a sample of six architectural projects in the masonry placement process was chosen, excluding those in which this phase had already been completed. To collect data from the workers in this sample, the entire workforce was used, that is: 49 workers.

Analysis of the results

Data analysis began with normality tests for each factor, using a statistical program that applied the Shapiro-Wilk (SW) test. This test provided a P value, which indicates the homogeneity of the data and is interpreted according to a standard threshold of 0.05. If the P value resulting from the SW test is greater than 0.05, the factor is considered to follow a normal distribution. On the other hand, if the P value is less than this threshold, it is concluded that the data do not meet the normality criteria.

Following the normality analysis, a correlation method was chosen between the different factors present in Table 1 and the performance of the workers at each site. In this particular case, the Kruskal-Wallis (KW) analysis was used, which does not require normality assumptions to establish correlations. The KW analysis evaluates the level of association through the chi-square test (χ^2), the degrees of freedom (df) and the level of significance (p), thus providing a robust measure of the relationship between variables without depending on the distribution of the data.

Following the correlational analysis, the mathematical model is built based on a multiple linear regression. This regression is divided into two distinct stages. The first stage involves the use of adjustment measures that reveal the effectiveness of the model. This is achieved through the linear correlation coefficient (R) together with the coefficient of determination (R^2), which indicate the strength and representativeness of the variables in the model.

In addition, essential metrics such as AIC (Akaike Information Criterion), BIC (Bayesian Information Criterion) and RMSE (Root Mean Square Error) have been incorporated into the analysis. AIC and BIC have different functions: they facilitate model comparison by taking into account both goodness of fit and complexity, while RMSE quantifies model accuracy by measuring discrepancies between observed and expected values.

In the second stage of linear regression, the coefficients of the model are calculated. These coefficients can be classified into three main types, one of which is the Estimator Coefficient (EC) which represents the link between the independent and dependent variables. The EE coefficient quantifies the precision of this estimate, while the t coefficient evaluates the level of deviation of this value from zero. The p coefficient quantifies the probability of observing this connection if there is no genuine relationship between the variables.

Results

The first test used on the collected data was Shapiro-Wilk to check assumptions of normality, showing p values ≤ 0.001 in all the data sets of the factors, therefore, there is no certainty or statistical evidence that the information follows a normal distribution and homogeneity. Since the distribution does not meet normality criteria to perform the correlation, the Kruskal-Wallis analysis was used for the data groups. These results are shown in Table 2.

The Kruskal-Wallis analysis yielded statistically significant findings for several factors impacting workers' job performance. The analyzed data demonstrate remarkable consistency in their statistical significance, as indicated by highly significant Chi-square (χ^2) values ($p < .001$) across all categories studied. Several factors, including physical variables such as temperature, soil, and cover, as well as elements related to the work environment such as management, training, and supervision, significantly impacted work efficiency. This analysis examines the relationship between various factors and productivity in architectural construction sites. It emphasizes the complex nature of job performance and provides a solid foundation for implementing improvement strategies in similar work environments.

Table 2

Results of Kruskal-Wallis analysis for factors affecting job performance

Variable	χ^2	gl	p
Time	24.4	5	< .001
Temperature	29.9	5	< .001
Floor	35.4	5	< .001
Deck	26.2	5	< .001
Difficulty	25.5	5	< .001
Danger	38.1	5	< .001
Continuity	31.4	5	< .001
Order and cleanliness	31.5	5	< .001
Work base	33.6	5	< .001
Typicality	35.3	5	< .001
Block	36.5	5	< .001
Tool	29.1	5	< .001
Equipment	22.3	5	< .001
Maintenance	22.5	5	< .001
Supply	26.6	5	< .001
Protective element	38.2	5	< .001
Address	38.0	5	< .001
Instruction	33.3	5	< .001
Follow-up	33.3	5	< .001
Calif. Master	27.5	5	< .001
Aserg. Quality	33.3	5	< .001
Personal Sit.	27.5	5	< .001
Fatigue	21.2	5	< .001
Ability	38.0	5	< .001
Knowledge	38.0	5	< .001
Training	27.5	5	< .001

After performing the KW analysis, the mathematical model based on multiple linear regression is formed. In this case, the first result shown by the statistical program was the model's fit measures. As can be seen in Table 3, the data show a strong correlation ($R = 0.968$) and a high level of predictability (adjusted $R^2 = 0.937$), suggesting that almost 93.3% of the variation in task performance can be attributed to these variables. The presence of negative values in both AIC (-99.1) and BIC (-73.9) indicates a very favorable fit of the model to the observed data. In addition, the low value of the root mean square error (RMSE) of 0.0255 highlights the high accuracy of the model to predict job performance using these characteristics.

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Table 3

Model fit measures

Model	R	Corrected R^2	AIC	BIC	RMSE
1	*0.968*	*0.933*	*-99.1*	*-73.9*	*0.0255*

The second notable finding, derived from the linear regression analysis, focuses on the coefficients of the model. When examining Table 4, it can be seen that the independent variables, evaluated individually, do not exhibit a significant correlation with the workers' performance. This result is supported by the calculated p values, which exceed the threshold of 0.05. Consequently, it can be inferred that, at the individual level, these variables do not have a statistically significant influence on the workers' job performance in the activity studied.

Regarding the estimators, the presence of two different directions for VI stands out, as established by the model. It is observed that the VIs of soil, cover, danger, preceding activity, typicality, cut, supply, monitoring and supervision show negative estimators, indicating an inverse relationship with job performance. That is, an increase in these variables is associated with a decrease in performance. On the other hand, the remaining variables present positive estimators, indicating a direct proportional relationship with performance, where an increase in these VIs is related to an increase in job performance.

Table 4

Model Coefficients - Performance

Predictor	Estimator	EE	t	p
Constant	1.7887	1.2793	1.398	0.185
Time	0.0863	0.0849	1.016	0.328
Temperature	0.1174	0.1100	1.067	0.305
Floor	-0.6763	0.8077	-0.837	0.418
Deck	-0.2479	0.1385	-1.790	0.097
Difficulty	0.4917	0.6010	0.818	0.428
Danger	-0.0212	0.1412	-0.150	0.883
Interruptions	0.8660	0.9334	0.928	0.370
Order and cleanliness	0.0400	0.0773	0.517	0.614
Previous activities	-0.2083	0.1724	-1.208	0.248
Typicality	-0.1278	0.0635	-2.012	0.065
Tajo (Workspace)	-0.5193	0.7314	-0.710	0.490

Model Coefficients - Performance

Predictor	Estimator	EE	t	p
Tool	0.3254	0.2292	1.420	0.179
Equipment	0.1263	0.0933	1.354	0.199
Supply	-0.0177	0.0542	-0.327	0.749
Follow-up	-0.0256	0.0411	-0.624	0.543
Supervisor (Teacher)	-0.0312	0.0452	-0.689	0.503

Once the coefficients have been calculated, the estimating coefficient is used to build the model through the general formula of multiple linear regression, and it is as follows:

*Y = 1.7887 + 0.0863 * time + 0.1174 * temperature - 0.6763 * floor - 0.2479 * roof + 0.4917 * difficulty - 0.0212 * danger + 0.8660 * Interruptions + 0.0400 * Order and cleanliness - 0.2083 * preceding activities - 0.1278 * typicality - 0.5193 * cut + 0.3254 * tool + 0.1263 * equipment - 0.0177 * supply - 0.0256 * monitoring - 0.0312 * supervisor*

In order to validate the effectiveness of the proposed model, a comparison is made between the actual average yields achieved by the workers, the theoretical yield provided by the Cuenca Autonomous Decentralized Gad (GAD) which is 1.25 m2/hour and the yields determined by applying the multiple linear regression formula presented previously. This comparison was made for each of the works analyzed and is presented below in Table 5. As shown in the table, the climatic conditions, the work activity, the available equipment, the supervision, the individual capacities of the worker and the working conditions varied between the different works. This variability was reflected in the levels of performance obtained, which were not uniform in all cases.

In construction site 1, the yields ranged between 1.22 and 1.27 m2/hour, while in construction site 2 the variation was between 1.20 and 1.27 m2/hour. On the other hand, in construction site 3, the yields varied significantly, between 0.98 and 1.25 m2/hour, in construction site 4 the variation was between 0.99 and 1.10 m2/hour, in construction site 5 a variation was observed between 1.01 and 1.15 m2/hour, in construction site 6, they ranged between 1.00 and 1.05 m2/hour. On the other hand, in construction site 7 the variation was between 1.06 and 1.27 m2/hour, in construction site 8 between 1.22 and 1.27 m2/hour and in construction site 9 between 1.10 and 1.27.

These data reveal two important aspects. Firstly, only in 12 cases did the workers' output reach or exceed the theoretical output stipulated by the GAD of Cuenca, which is 1.25 m2/hour, while in the other cases the output was below this figure. Secondly, it can be seen that the workers' output does not follow a linear trend, and that even within the same building there can be significant variations in output.

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Table 5

Comparison of worker performance based on indicators

Construction site	Worker	Time	Temperature	Floor	Deck	Difficulty	Danger	Interruptions	Order and cleanliness	Previous activities	Typicality	Tajo (Workspace)	Tool	Equipment	Supply	Follow-up	Supervisor (Teacher)	Actual performance	Calculated performance data	Performance of the Cuenca GAD
1	1	4	5	4	4	3	2	4	3	4	3	5	3	3	5	4	4	1.27	1.26	1.25

Table 5

Comparison of worker performance based on indicators (continued)

Construction site	Worker	Time	Temperature	Floor	Deck	Difficulty	Danger	Interruptions	Order and cleanliness	Previous activities	Typicality	Tajo (Workspace)	Tool	Equipment	Supply	Follow-up	Supervisor (Teacher)	Actual performance	Calculated performance data	Performance of the Cuenca GAD
	2	5	4	4	5	2	3	5	3	5	3	5	3	4	5	4	4	1.22	1.25	1.25
	3	5	4	4	4	3	2	4	4	5	4	5	4	3	5	5	4	1.22	1.23	1.25
	4	4	4	5	4	2	3	5	3	5	3	4	3	4	4	4	5	1.25	1.25	1.25
	5	5	4	4	4	3	2	4	3	4	3	5	3	3	5	5	4	1.22	1.21	1.25
	6	4	4	5	5	3	2	4	3	4	3	4	4	4	4	4	4	1.27	1.21	1.25
	1	4	4	4	5	3	2	4	4	4	3	5	4	3	5	5	5	1.21	1.21	1.25
	2	5	4	5	4	2	3	5	3	5	3	4	3	3	4	4	5	1.21	1.21	1.25
2	3	5	4	4	4	3	2	4	3	4	3	5	3	3	5	5	4	1.20	1.21	1.25
	4	4	5	4	4	3	2	4	3	4	3	5	3	3	5	4	4	1.26	1.26	1.25
	5	5	4	4	4	3	2	4	4	5	4	5	4	3	5	5	4	1.25	1.23	1.25
	6	4	5	4	4	3	2	4	3	4	3	5	3	3	5	4	4	1.27	1.26	1.25
	1	5	4	4	5	2	3	5	3	5	3	5	3	4	5	4	4	1.25	1.25	1.25
	2	3	4	3	3	2	1	3	2	3	2	4	2	2	4	4	3	1.07	1.06	1.25
3	3	4	3	3	4	1	2	4	2	4	2	4	2	3	4	3	3	1.06	1.08	1.25
	4	4	3	3	3	2	1	3	3	4	3	4	3	2	4	4	3	1.07	1.06	1.25
	5	4	3	3	2	1	3	2	3	2	4	2	2	3	3	3	4	1.05	1.05	1.25

	6	3	3	4	4	2	1	3	2	3	2	3	3	3	3	3	3	0.98	1.03	1.25
4	1	4	3	4	3	1	2	4	2	4	2	3	2	2	2	3	4	1.00	1.05	1.25
	2	4	3	4	3	4	3	2	1	4	2	3	2	4	2	4	3	0.99	0.99	1.25
	3	4	3	3	4	1	2	4	2	4	2	4	2	3	4	3	4	1.05	1.05	1.25
	4	4	3	4	4	2	1	4	3	4	3	4	3	2	4	4	3	0.99	1.00	1.25
	5	3	3	4	4	2	1	4	2	4	2	4	3	3	4	4	4	1.10	1.10	1.25
	6	4	3	4	4	2	1	4	3	4	2	4	3	2	4	4	4	1.10	1.10	1.25
5	1	4	3	3	4	1	2	4	2	4	2	4	2	3	4	3	3	1.15	1.08	1.25
	2	4	3	4	3	1	2	4	2	4	2	3	2	2	2	3	4	1.10	1.05	1.25
	3	3	4	3	3	2	1	3	2	3	2	4	2	2	4	4	3	1.05	1.06	1.25
	4	4	3	4	4	2	1	4	3	4	3	4	3	2	4	4	3	1.01	1.00	1.25

Table 5

Comparison of worker performance based on indicators (continued)

Construction site	Worker	Time	Temperature	Floor	Deck	Difficulty	Danger	Interruptions	Order and cleanliness	Previous activities	Typicality	Tajo (Workspace)	Tool	Equipment	Supply	Follow-up	Supervisor (Teacher)	Actual performance	Calculated performance data	Performance of the Cuenca GAD
	5	4	3	4	4	2	1	4	3	4	3	4	3	2	4	4	3	1.01	1.00	1.25
6	1	3	4	3	3	2	1	3	2	3	2	4	2	2	4	4	3	1.05	1.06	1.25
	2	4	3	3	3	2	1	3	3	4	3	4	3	2	4	4	3	1.05	1.06	1.25
	3	4	3	3	2	1	3	2	3	2	4	2	2	3	3	3	4	1.05	1.05	1.25
	4	3	3	4	4	2	1	3	2	3	2	3	3	3	3	3	3	1.00	1.03	1.25
	5	4	3	4	3	1	2	4	2	4	2	3	2	2	2	3	4	1.00	1.05	1.25
	6	4	3	4	3	4	3	2	1	4	2	3	2	4	2	4	3	1.00	0.99	1.25
7	1	5	4	4	4	3	2	4	4	5	4	5	4	3	5	5	4	1.25	1.23	1.25
	2	4	5	4	4	3	2	4	3	4	3	5	3	3	5	4	4	1.27	1.26	1.25
	3	5	4	4	5	2	3	5	3	5	3	5	3	4	5	4	4	1.25	1.25	1.25
	4	3	4	3	3	2	1	3	2	3	2	4	2	2	4	4	3	1.07	1.06	1.25
	5	4	3	3	4	1	2	4	2	4	2	4	2	3	4	3	3	1.06	1.08	1.25
	6	4	3	3	3	2	1	3	3	4	3	4	3	2	4	4	3	1.07	1.06	1.25
8	1	4	5	4	4	3	2	4	3	4	3	5	3	3	5	4	4	1.27	1.26	1.25
	2	5	4	4	5	2	3	5	3	5	3	5	3	4	5	4	4	1.22	1.22	1.25
	3	5	4	4	4	3	2	4	4	5	4	5	4	3	5	5	4	1.22	1.23	1.25

	4	4	4	5	4	2	3	5	3	5	3	4	3	4	4	4	5	1.25	1.25	1.25
	1	5	4	4	4	3	2	4	3	4	3	5	3	3	5	5	4	1.22	1.21	1.25
	2	4	4	5	5	3	2	4	3	4	3	4	4	4	4	4	4	1.27	1.21	1.25
9	3	4	4	4	5	3	2	4	4	4	3	5	4	3	5	5	5	1.21	1.21	1.25
	4	3	3	4	4	2	1	4	2	4	2	4	3	3	4	4	4	1.10	1.10	1.25

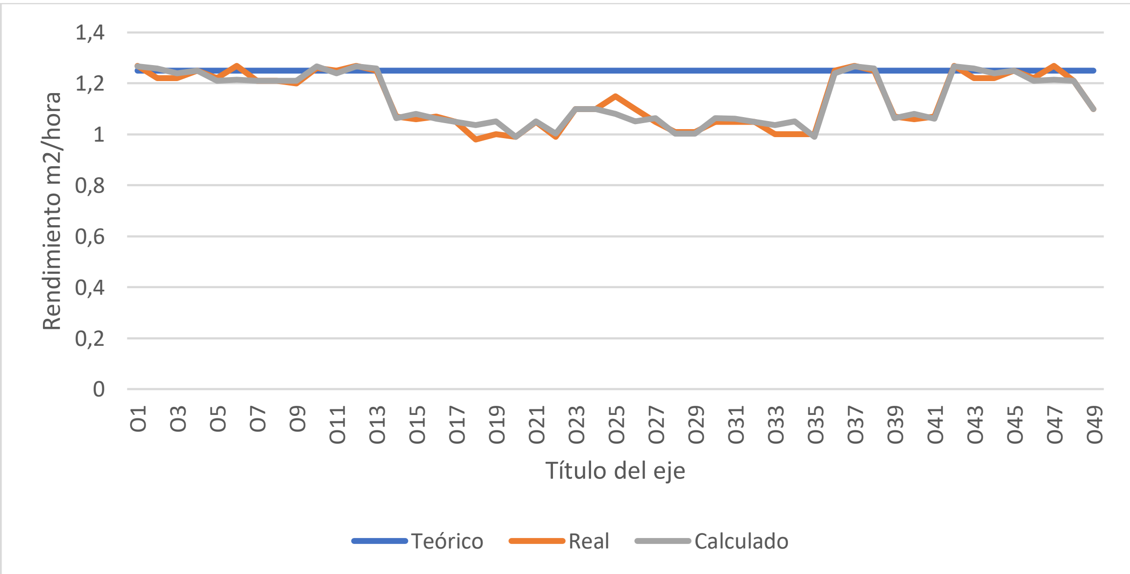
To more effectively illustrate the fluctuations in workers' performance, Figure 1 presents a graphic representation that compares the actual performance of workers, the theoretical performance established by the Cuenca GAD and the performance calculated using the mathematical model.

As can be seen, the actual performance of workers does not follow a linear trend, but fluctuates significantly and is often below the expected performance. This suggests that if a construction manager bases his plans solely on theoretical average performance, he is likely to face delays or missed delivery times.

In contrast, the performance calculated using the mathematical model adjusts satisfactorily to these variations. This provides a more realistic average of the performance that can be expected, taking into account the various external and internal conditions that affect workers.

Figure 1

Comparison of average real and theoretical yields of work 1



Conclusions

- When exploring the individual correlations between the independent variables in this study, it was found that no factor analyzed exerts, on its own, a significant influence on job performance. However, the conjunction of these factors allows the performance of a worker to be predicted with an accuracy of up to 93.3% according to the statistical analysis performed (R2corrected). The similarity between the estimated theoretical performance and the actual average performance of the workers supports the effectiveness of linear regression to anticipate these performances based on the various factors evaluated.
- The mathematical model derived from linear regression, presented in this research, is revealed as a powerful tool to predict the performance of the work crews in the Cañaribamba Parish, considering both external and internal factors of the work. This application could result in the significant optimization of execution times and the reduction of costs associated with delays and failure to meet deadlines in construction projects. This model can be extrapolated to other parishes in Cuenca that have a similar context and conditions similar to those presented in this document.

Conflict of interest

There is no conflict of interest

Gratitude

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