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Propuesta de modelo matemático de rendimiento de mano de obra en enlucidos de mampostería. Caso de estudio: ciudad de Cuenca

Proposal of a mathematical model of labor performance in masonry plastering. Case study: city of Cuenca

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Palabras claves:
Rendimiento de mano de obra, Enlucido, Modelo matemático, Regresión lineal.

Resumen

Introducción. La predicción del rendimiento de la mano de obra en la actividad de enlucido con mampostería es crucial para garantizar una planificación eficiente en el sector de la construcción. Una predicción precisa de esta actividad es vital para evitar retrasos, controlar los costos y cumplir con los plazos contractuales, lo que resalta la importancia de este estudio en la optimización de procesos constructivos. **Objetivo.** El propósito de esta investigación es presentar un modelo matemático para anticipar el rendimiento de la mano de obra en la actividad de enlucido de mampostería con mortero, empleando una técnica de regresión lineal. **Metodología.** Se adoptó un diseño metodológico relacional-descriptivo, que comenzó con una revisión de la literatura para identificar los factores que influyen en el rendimiento de los trabajadores. Posteriormente, se diseñó un instrumento de recolección de datos que se aplicó a una muestra de siete obras registradas en la base de datos del GAD municipal de Cuenca, ubicadas en la fase de enlucido con mortero en la parroquia de Yanuncai. Los datos recopilados se analizaron utilizando un programa estadístico, lo que permitió desarrollar un modelo matemático para prever el rendimiento de los trabajadores en función de los factores estudiados. **Resultados.** Los resultados revelaron que el modelo desarrollado puede predecir de manera efectiva el rendimiento de los trabajadores considerando tanto los factores externos como internos de la obra. Se encontró que, para la actividad de enlucidos de mampostería, solo ciertos factores, como el tiempo, la temperatura, el tipo de suelo, las características de la cubierta, el nivel de dificultad, los riesgos asociados, los métodos de trabajo y la habilidad del trabajador, pueden prever este rendimiento mediante la regresión lineal. **Conclusión.** En conclusión, se evidencia que el rendimiento teórico no es eficaz para predecir el rendimiento real de la mano de obra, y se destaca la eficacia de la regresión lineal para mejorar la capacidad de planificación de tiempos de ejecución de los administradores del sector de la construcción en la ciudad de Cuenca. **Área de estudio general:** Ingeniería, Industria y Construcción**. Área de estudio específica:** Administración de la Construcción

Keywords:

Abstract

Labor performance, Plastering, Mathematical model, Linear regression, linear regression

Introduction. The prediction of labor performance in the masonry plastering activity is crucial to ensure efficient planning in the construction industry. Accurate prediction of this activity is vital to avoid delays, control costs and meet contractual deadlines, which highlights the importance of this study in the optimization of construction processes. objective. The purpose of this research is to present a mathematical model to anticipate labor performance in the activity of masonry plastering with mortar, using a linear regression technique. Methodology. A relational-descriptive methodological design was adopted, which began with a literature review to identify the factors that influence workers' performance. Subsequently, a data collection instrument was designed and applied to a sample of seven construction sites registered in the database of the GAD municipal of Cuenca, located in the mortar plastering phase in the parish of Yanuncai. The data collected were analyzed using a statistical program, which allowed the development of a mathematical model to predict the performance of workers according to the factors studied. Results. The results revealed that the model developed can effectively predict the performance of the workers considering both external and internal factors of the construction site. It was found that, for the masonry plastering activity, only certain factors, such as time, temperature, soil type, roof characteristics, level of difficulty, associated risks, work methods and worker skill, can predict this performance using linear regression. Conclusion. In conclusion, it is evident that theoretical performance is not effective in predicting actual labor performance, and the effectiveness of linear regression in improving the planning capacity of construction sector managers in the city of Cuenca is highlighted.

Introduction

The Construction Industry (CI) is widely recognized as a very promising economic sector with significant growth potential on a global scale (Pheng and Hou, 2019). In this context, Ecuador is also experiencing the positive impact of this trend. The aforementioned sector has not only consistently contributed to the growth of the economy of this country, but has also played a fundamental role in generating employment opportunities (Díaz et al., 2022). This statement is supported by data obtained from the Central Bank of Ecuador, which reveal that every 40m2 of construction activity results in a duration of 18 months of employment in civil works. During the initial quarter of 2023, this phenomenon resulted in the involvement of approximately 495,000 employees, subsequently generating a domino effect in various sectors of commerce and industry (Osorio and Cazares, 2019).

As previously mentioned, IC is experiencing an increase in demand across the country currently (Flores et al., 2019). It is crucial to recognize that, in the city of Cuenca, this phenomenon has been further amplified by urban expansion and population growth, resulting in an increased need for construction projects (Flores and Carrera, 2022). With this scenario in mind, the need for entities, companies, engineering, architecture and construction professionals in general who are dedicated to this work to be able to stand out in a highly competitive environment is underlined (Azeem et al., 2020). To remain relevant in the market, it is important for organizations to prioritize the efficient management of resources and the optimization of construction processes (Zhang et al., 2021).

In the aforementioned context, which is characterized by increasing competition, the importance of effective management to maintain competitiveness within the market takes on great importance. One of the crucial elements to achieve this goal is the effective management and increase in worker productivity which is measured through their performance or commonly referred to as Labor Performance or by its acronym RMO (Oboreh et al., 2022). This aspect shows interconnections with several other important concepts including operations control, process execution, activity planning and application of studies (Castillo et al., 2021). Furthermore, it is worth noting that, in the context of Ecuador, where labor expenses represent approximately 28% to 40% of total construction expenses, the effective implementation of RMO assumes a fundamental role for construction companies operating within an increasingly competitive market (Valdez and Toledo, 2021).

Despite the above, the calculation of RMO in the Ecuadorian context remains limited in terms of robust standardization or methods that enable accurate prediction of a worker's potential performance, considering various factors that may influence said performance (Encalada and Calle, 2021). This lack of standardization increases uncertainty among management, which can lead to situations where actual worker performance is significantly lower than expected. This, in turn, triggers delays, interruptions in work continuity, increased costs, and hinders the progress of subsequent phases of the project, which depend on the timely completion of previous activities (Tola et al., 2023).

An example of construction activities that can cause delays, but are often not considered critical in planning, is masonry plastering with 1:3 mortar. This procedure involves the direct application of layers of mortar onto the surface of the masonry, with the purpose of improving the uniformity and aesthetics of the walls. Although commonly underestimated, this activity can have a significant impact on the project if not properly addressed in planning. Indeed, its poorly managed execution could lead to considerable delays, contributing to increased costs and complicating the development of the project as a whole (Mahzuz et al., 2020).

Given the aforementioned problem, the following research question is posed: How can the planning and management of masonry plastering with 1:3 mortar be improved to avoid delays and additional costs in construction projects? To answer this question, the following objective is posed: Propose a mathematical model to predict labor performance in the masonry plastering with mortar activity through the application of linear regression to improve the execution time planning capacity of construction sector managers in the city of Cuenca.

The importance of fulfilling the proposed objective of this research is to mitigate avoidable delays and additional expenses caused by inefficient planning of the workers' performance in the mortar plastering activity. By addressing this issue, both construction professionals and companies will obtain an important tool to carry out their planning efficiently, thus reducing the uncertainty generated in this activity. Likewise, this research will provide a technical contribution that can be implemented to improve budgets when quantifying the performance of labor in the execution of items in the construction of mortar plastering.

This research is carried out in the city of Cuenca, a population environment characterized by being a sector with large territorial expansions where construction demand has increased considerably (Herrera et al., 2023). The dependent variable of this research is the RMO, which can be defined as the amount of work performed by a worker over the measured unit of time. For its part, the independent variables are all the factors that can influence the RMO, which can be: climatic factors, the type of activity carried out by the workers, the type and quality of the tools provided, the type of supervision carried out on the site, and the conditions of the worker. The theoretical framework used to characterize each of the aforementioned variables is presented below:

Factors affecting labor performance

Before specifically addressing the issue raised about the factors that affect labor performance, it is important to begin by defining what RMO is and what implications it has on construction works.

The concept of performance can be defined as the ability of an individual, team or system to achieve goals and objectives using available resources, that is, it evaluates the effectiveness and efficiency in the performance of tasks and the achievement of the desired results (Adebowale and Agumba, 2022). In the field of construction, specifically concerning RMO, it can be defined as the volume of work or production that a worker is capable of producing per unit of time in an established period, that is, it is the efficiency with which a worker is capable of carrying out an activity during his working day that can be measured as: amount of work/unit of time, where the units will depend on the type of activity carried out and the periods of time used by the company (Sugiyanto et al., 2022).

The impact of job performance on construction sites is of considerable importance as it has a direct influence on the productivity and efficiency of the work being performed. In case job performance is not optimal, there is a possibility that the project completion time will be prolonged, leading to higher expenses and delays in project delivery. Furthermore, poor job performance has the potential to compromise the quality of work and increase the likelihood of workplace accidents. Therefore, it is crucial to know the variables that influence job performance and implement measures to improve them (Valdez and Toledo, 2021).

The importance of understanding these determinants, as this understanding allows for optimizing construction processes and reducing costs in housing projects. By understanding the various factors that affect worker performance, it is possible to discern opportunities to improve work planning and execution. This, in turn, can result in greater efficiency and productivity on the construction site. Furthermore, optimizing construction processes can produce favorable results in terms of construction quality and customer satisfaction (Abdelnour, 2022).

Currently, there are several factors or variables that can influence the RMO, an example of this is the research carried out by Luis Fernando Botero who points out several causes that can reduce or improve these yields that are classified into 5 categories and are mentioned below (Botero, 2002):

Environmental conditions: such as rain, prolonged exposure to sunlight, the use of covers and temperature, can affect the performance of workers, depending on the intensity of these conditions and the duration of exposure. The second category corresponds to the type of activity in question. Elements such as difficulty, inherent risk, typicality and work area can directly influence the type of performance that can be expected.

The type of equipment constitutes another relevant category. The quality, availability and timely maintenance of tools can determine the effectiveness of the performance obtained by a worker. The fourth category refers to supervision. Botero argues that RMO is intrinsically linked to the supervision conditions present in the workplace. Finally, the fifth category highlights the conditions of the worker himself. Factors such as personal situation, level of knowledge, training and level of fatigue play a crucial role in his performance. These identified categories provide a clear overview of the variables that have an impact on RMO, highlighting the complexity and multiplicity of factors that influence the productivity of workers in the construction field.

Methodology

The methodological design used in this research corresponds to the relational-descriptive type, since the influence that different external and internal factors have on the workers' performance in the masonry plastering activity will be verified. Likewise, a quantitative approach is used, since the data and analysis used in the development of the entire research are carried out statistically through numerical analysis software.

The dependent variable of this research is the labor performance of employees working in the mortar plastering industry. The independent variables are the factors that are capable of influencing this variable. Table 1 presents the independent variables used for the research, which correspond to: climatic conditions, type of activity performed by the workers, type of equipment, type of supervision implemented at the site, and the conditions of the workers who are not part of the contracting organization or company.

The research universe addresses the architectural structures located in the city of Cuenca, Ecuador, specifically those that are in the mortar plastering phase and that are in the database of the GAD of Cuenca. The selection of the population under study focused on the buildings in progress within the parish of Yanuncai. This population was chosen due to the presence of works in progress in the aforementioned construction stage. To determine the sample, a non-random sampling approach was adopted, with an emphasis on the constructions that were, at the time of carrying out this research, in the plastering phase. This type of specific sampling is classified as convenience sampling, which guaranteed a precise focus on the object of study in question and resulted in a total of 7 works within the aforementioned parish.

To collect the data, all the workers who were carrying out the plastering activity with mortar at the time of data collection were used, and it began with an exhaustive characterization of the workers, requesting general information about their activities on the works. This phase allowed the personnel to be classified into two categories: the bricklayers, responsible for carrying out the plastering with masonry, and the assistants/laborers, in charge of tasks such as cleaning, preparing mixtures and placing formwork for the edges.

Once the characterization was completed, data collection was carried out using an observation sheet designed based on the independent variables and their respective indicators, detailed in Table 1. These data were translated into numerical equivalents and entered into statistical analysis software to perform normality calculations, analysis of variance, correlation between variables and the determination of a linear regression. These analyses allowed the creation of a mathematical model that estimates the labor performance in plastering work with masonry.

Table 1

Independent variables and indicators

Variable	Indicators	1	2	3	4	5
Climate	Time	Storm	Downpour	Drizzle	Cloudy	Clear
	Temperature	Very Hot/VeryCold		Hot/Cold		Cool
	Floor	Swampy	Puddles	Wet floor	Dry floor	Hard floor
	Deck	Sun		Normal		Shade
Activity	Difficulty	Difficult		Normal		Easy
	Danger	Dangerous	Risky	Normal	Moderate	No danger
	Interruptions	≥ 1 hour	15≥60 min	5≥15 min	0≥5 min	None
	Order and cleanliness	Difficult access	Rubbish	Passable	Little dirt	Total cleanliness and order
	Previous activities	Repeat	A lot of healing	Little healing	Acceptable	Perfect

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Table 1

Independent variables and indicators (continued)

Variable	Indicators	1	2	3	4	5
Equipment	Typicality	From 1 to 5	From 5 to 10	From 10 to 15	From 15 to 20	More than 20
	Tajo (Workspace)	Very narrow	Narrow	Normal	Broad	Very spacious
	Tool	Inadequate		Adequate		Special
	Equipment	Inadequate		Adequate		Special
	Maintenance	Null		Acceptable		Well
	Supply	Never		Sometimes		Always
	Protective element	None		Almost all		All
Supervision	Address (acceptance criteria)	None	Informal	Verbal	Previous verbals	Under written
	Instruction	None		Verbal - required		Required document
	Follow-up	No review		Eventual review		Always
	Supervisor (Teacher)	Bad		Regular		Well
	Quality Assurance	It does not exist	Isolated efforts	Inventory	In progress	ISO Certificate
Worker	Personal situation	Neurotic	Sad	Normal	Good	Excellent
	Work pace	Slow		Normal		Fast
	Health	Sick		Normal		Excellent
	Ability	Inexperienced		Skilled		Expert
	Training	None	Apprentice	Required	Expert	Certificate
Labor	Contract	Administration				Outsourcing
	Union	Yeah				No
	Incentives	No				Yeah
	Salary	SMLV				≥SMLV
	Social security	Yeah				No

*Note.*Adapted from Botero (2002)
Prepared by: Karla Denisse Campoverde Chicaiza (2023)

To assess the normality of the data, the Shapiro-Wilk test was used, which is known for its ability to determine whether the data collected adhere to a normal distribution and whether their variances are homogeneous. This test is based on obtaining a P value, with a standard threshold set at p-value=0.05. In this context, a P value greater than 0.05

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indicates a normal distribution of the data, while a lower P value suggests that the data do not meet the assumptions of normality.

Analysis of variance was determined by assessing the normality of the data. In this study, the Kruskal-Wallis method was applied, which employs the calculation of a chi-square (χ^2) value. This statistical measure allows us to determine whether there is a substantial correlation between categorical data sets. The degrees of freedom (df) in this study represent the number of independent variables that can be modified without affecting the established restrictions. In addition, a predetermined level of significance (p) was taken into account, which establishes the threshold for determining whether the study findings are statistically significant or simply a consequence of chance. The level of significance is normally set at conventional levels, such as 0.05 or 0.01. However, it can be modified depending on the specific circumstances and the desired level of precision for the research being conducted.

Next, the linear regression calculation begins with the model fit measures through: The linear correlation coefficient (R) quantifies the magnitude and direction of the association between variables, while the coefficient of determination (R^2) measures the fraction of variability accounted for by the model. The Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) are metrics that evaluate the relative quality of a model with the aim of decreasing its values to determine the best fit. The root mean square error (RMSE) quantifies the difference between the predicted and observed values, and serves as a measure of the model's accuracy in predicting actual outcomes. These metrics provide a complete and accurate assessment of the statistical model's predictive ability and suitability for the data under investigation.

The model coefficients are then calculated using the performance metrics and independent variables clarified in Table 1. Some of the key coefficients of the model include: The estimator value represents the calculated slope or correlation between the independent variable and the dependent variable in the model. The SE coefficient measures the precision of the coefficient estimate and quantifies the variability of the estimate across samples. The t coefficient is used to assess whether the coefficient deviates significantly from zero. The p coefficient indicates the probability of observing the coefficient if there is no true relationship between the variables.

Once the coefficient values have been obtained, one can proceed with the estimation of the general formula of the mathematical model based on linear regression, which has the following base form:

$$y = b_0 + b_1 * X1 + b_2 * X2 + \cdots + b_N * Xn$$

Where:

- y= Variable of interest or dependent variable
- X1, X2,…,Xn = independent variables
- b0= independent term, expected value of y when X1,…,Xn are zero
- b1=measures change in y for each unit change in X1, holding X2, X3,…,Xn constant
- b2= measures the change in y per unit change in X2, holding X1, X3,…,Xn constant
- bn= measures the change in y for each unit change in Xn, holding X1,…,Xn-1 constant

Results

Before starting the analyses, the data were tested for normality using the Shapiro-Wilk test. The results suggest that the data do not fit a normal distribution and that the variances are not equal (p-value <0.05 in all tests). Due to the lack of conformity to the normality and homogeneity requirements, conventional analysis of variance (ANOVA) is not suitable. Alternatively, we opted to use the Kruskal-Wallis test, which is a non-parametric alternative that avoids the need for normality assumptions. This test allows the comparison of medians between several groups even when the data do not fit a normal distribution.

As seen in Table 2, the Kruskal-Wallis analysis demonstrated strong evidence ($p < .001$ for most variables) of discrepancies in job performance in relation to various factors assessed. This was corroborated by chi-square (χ^2) statistics that ranged from 8.31 to 29.00, with 3 degrees of freedom in each case. The results demonstrate statistically significant variations between the samples assessed, covering factors such as duration, temperature, difficulty, interruptions, tools used, and safety environments. In other words, the Kruskal-Wallis analysis demonstrates that the factors used do have a significant impact on the performance variable.

Table 2

Kruskal-Wallis analysis

Factor	X2	gl	p
Time	29.00	3	< .001
Temperature	27.55	3	< .001
Floor	19.92	3	< .001
Deck	29.00	3	< .001
Difficulty	21.08	3	< .001
Danger	8.31	3	0.040
Interruptions	29.00	3	< .001
Order and cleanliness	27.55	3	< .001

Previous activities	29.00	3	< .001
Tajo (Workspace)	21.21	3	< .001
Tool	29.00	3	< .001
Equipment	29.00	3	< .001
Maintenance	29.00	3	< .001
Supply	29.00	3	< .001
Protective element	21.21	3	< .001
Address (acceptance criteria)	29.00	3	< .001
Instruction	29.00	3	< .001
Follow-up	29.00	3	< .001
Supervisor (Teacher)	21.21	3	< .001
Quality Assurance	29.00	3	< .001
Personal situation	21.21	3	< .001
Work pace	29.00	3	< .001
Health	29.00	3	< .001
Ability	15.38	3	0.002
Training	29.00	3	< .001

Note: Statistical data determined from information collected from the target population.

After confirming the individual impact of the components on the RMO, we proceed to build the model using multiple linear regression in the JAMOVI tool. Table 3 presents the model fit measures, highlighting a significant correlation between the variables as the main result of the investigation. The independent variables (R and R2) account for approximately 99% of the variation in the dependent variable, suggesting that the model fits the data exceptionally well. The AIC and BIC values indicate a low level, implying that this model is more favorable. In addition, the forecasts present little error, indicating that the model estimates are very accurate and closely aligned with the actual values.

Table 3

Model fit measures

Model	R	R^2	AIC	BIC	RMSE
1	0.994	0.988	-123	-109	0.0221

Table 4 shows the coefficients of the model, illustrating the correlation between job performance and other parameters. The “Estimator” values represent the estimated impact of each component on performance. For example, the estimator for time is 0.1400, showing that an increase in time is linked to a 0.1400 increase in performance. On the other hand, the estimator for soil is -0.0700, implying that specific soil conditions are associated with a 0.0700 decrease in performance. The “t” and “p” values represent the statistical significance of each factor. The “t” value measures the extent to which the estimator deviates from zero, while the “p” value indicates whether this deviation is statistically significant. As an illustration, the variable temperature exhibits a p-value of 1.000, showing that it lacks a substantial influence on performance. In contrast, the difficulty and skill variables have p-values of 0.250 and 0.045 respectively, showing that they may have a somewhat less significant, but still significant, impact on task performance.

It is important to note that some predictors were not used in the calculation of the coefficients due to the low variability in their data. This lack of variation did not guarantee a solid contribution to the multiple linear regression model, which would compromise the reliability of the predictions. For this reason, those predictors that did not offer sufficient information were excluded from the analyses, keeping only those presented below.

Table 4

Model coefficients – performance

Predictor	Estimator	EE	t	p
Constant	0.5250	0.0926	5.67	< .001
Time	0.1400	0.0361	3.87	< .001
Temperature	2.20e-15	0.0286	7.70e-14	1,000
Floor	-0.0700	0.0153	-4.58	< .001
Deck	0.1550	0.0315	4.92	< .001
Difficulty	0.0350	0.0296	1.18	0.250

Table 4

Model coefficients – performance (continued)

Predictor	Estimator	EE	t	p
Danger	-0.0700	0.0246	-2.84	0.010
Tajo (Workspace)	-0.0700	0.0392	-1.78	0.089
Ability	0.0700	0.0328	2.14	0.045

Note: Data determined from the study sample.

With the coefficients calculated, the general formula of the model can now be estimated, using the estimators, resulting in the following formula:

$$y = 0.5250 + 0.14*Time + 2.20e\text{-}15*Temperature - 0.07*Ground + 0.155*Cover + 0.035*Difficulty – 0.07*Danger - 0.07*Cut + 0.07*Skill$$

Similarly, the standardized residuals were plotted against the theoretical quantiles, which, as seen in Figure 1, are very close to the distribution of the straight line.

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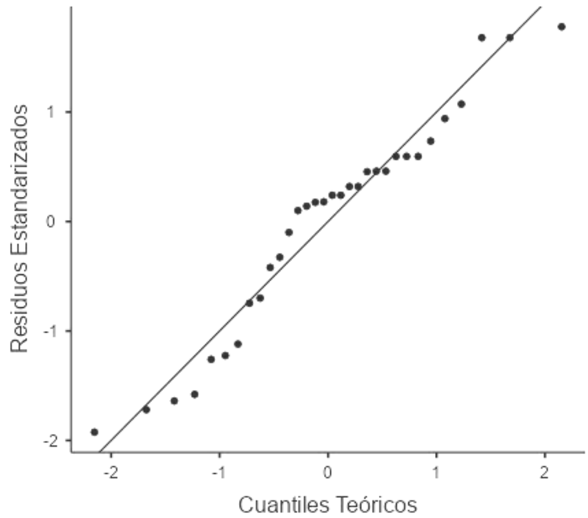
Figure 1.

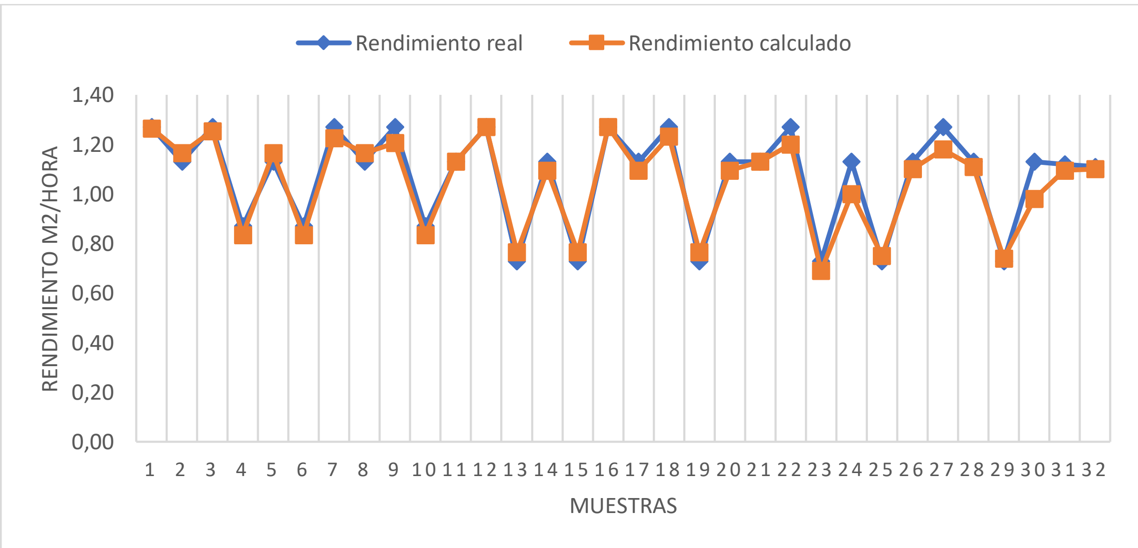
QQ Chart



To demonstrate the efficiency of the model to predict the performance of workers in the masonry plastering activity, Figure 2 presents a comparison between the actual average performance and the calculated performance or theoretical performance that was determined from the linear regression formula.

Figure 2.

Comparison of theoretical and actual performance



In order to validate the effectiveness of the determined formula, it was applied to six different construction sites from those used in the first data collection. In this phase, data were recorded regarding time, temperature, soil type, roof characteristics, level of difficulty, risks, work methods and skills of the workers, as well as the performance at the end of each day. This process was carried out over a full week, thus ensuring that the performance calculations obtained were consistent with the actual performance observed. In addition, these results were compared with the standard performance established by the Decentralized Autonomous Government (GAD) of the municipality of Cuenca for the activity of laying masonry plaster.

As shown in Figure 3, the estimated output by the Cuenca GAD is 1.3 m²/hour. However, the outputs of the workers on site 1 fluctuated throughout the days of data collection, with day 2 showing the lowest output and day 1 the highest output. The developed formula proved effective in accurately predicting the output of the workers, as the calculated values resemble the observed outputs. When analyzing the characteristics of the factors on these two specific days, it was observed that the only conditions that varied were the weather and the level of danger associated with the activity. On day 1, cloudy weather was recorded and the level of danger considered normal, given that the workers were on the first floor. On the other hand, on day 2, there was drizzle and a moderate level of danger, since the plastering was carried out on scaffolding.

Figure 3.

Comparison of performances in work 1 outside the sample

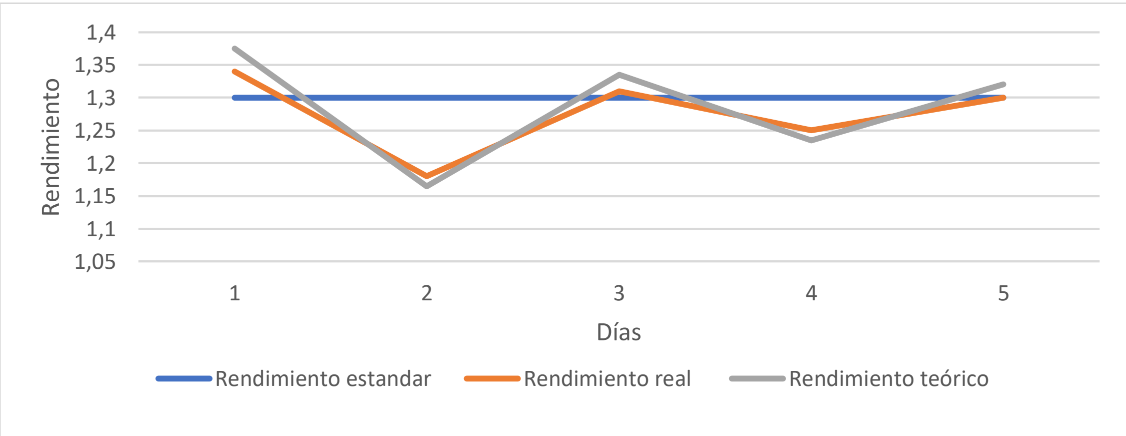


Table 4 below shows the standard performance values of the Cuenca GAD, the actual performance obtained by the workers and the theoretical performance calculated by the mathematical model based on the linear regression of the 6 works. As can be seen, the actual performance of the workers does not remain static, it varies depending on the conditions of each day and the formula is able to accurately anticipate these variations.

Table 3

Model coefficients – performance

Construction site	Day	Time	Temperature	Floor	Deck	Difficulty	Danger	Block	Ability	Standard Performance	Actual performance	Calculated performance
Work 1	1	4	3	3	3	3	3	3	5	1.3	1.34	1.38
	2	3	3	3	3	3	4	3	5	1.3	1.18	1.17
	3	4	1	4	5	3	4	4	3	1.3	1.31	1.34
	4	5	5	4	3	3	4	3	3	1.3	1.25	1.24
	5	4	3	4	4	3	3	3	3	1.3	1.3	1.32
Work 2	1	1	1	3	5	1	3	2	5	1.3	1.28	1.27
	2	1	1	2	5	1	2	3	5	1.3	1.31	1.34
	3	3	3	3	3	1	2	3	5	1.3	1.24	1.24
	4	1	1	2	3	1	1	2	5	1.3	1.18	1.17
	5	4	5	3	3	1	3	2	5	1.3	1.34	1.38
Work 3	1	2	1	2	5	1	1	3	5	1.3	1.35	1.55
	2	5	3	3	3	3	4	2	5	1.3	1.32	1.52

Table 3

Model coefficients – performance (continued)

Construction site	Day	Time	Temperature	Floor	Deck	Difficulty	Danger	Block	Ability	Standard Performance	Actual performance	Calculated performance
	3	5	5	3	3	3	3	3	5	1.3	1.32	1.52
	4	5	3	4	1	3	4	2	5	1.3	1.12	1.14
	5	5	3	4	3	3	4	3	5	1.3	1.25	1.38
	1	5	3	3	3	1	4	2	5	1.3	1.35	1.45
	2	5	1	4	1	1	3	3	5	1.3	1.12	1.07
Work 4	3	5	1	4	3	1	2	2	5	1.3	1.35	1.52
	4	5	1	4	1	1	2	4	5	1.3	1.12	1.07
	5	5	1	4	3	1	2	3	5	1.3	1.35	1.45
Work 5	1	3	3	3	3	3	3	3	3	1.3	1.12	1.10
	2	4	3	4	3	3	3	2	3	1.3	1.25	1.24
	3	3	1	3	5	3	3	4	3	1.3	1.35	1.34

	4	4	5	4	3	3	3	3	3	1.3	1.12	1.17
	5	4	3	4	3	3	3	2	3	1.3	1.12	1.24
	1	3	3	4	5	3	4	3	3	1.3	1.35	1.27
	2	2	1	3	5	3	3	2	3	1.3	1.35	1.34
Work 6	3	2	1	4	5	3	3	4	3	1.3	1.12	1.13
	4	4	5	4	3	3	3	3	3	1.3	1.12	1.17
	5	4	3	4	5	3	3	4	3	1.3	1.35	1.41

Discussion

The results obtained revealed that, although both external and internal factors of a construction site have the capacity to influence the performance of the workforce, when incorporated jointly into the mathematical model, only some of these factors are capable of accurately predicting the performance that a worker can achieve. In the context of masonry plastering activity, statistical analysis showed that only the factors of time, temperature, type of soil, characteristics of the roof, level of difficulty, associated risks, work methods and worker skill can make this prediction using linear regression.

Although the Cuenca GAD has an estimated performance of 1.3 m^2/hour, these values were not constant and fluctuated depending on the factors mentioned above, indicating that variations in conditions can influence worker performance. Therefore, to make accurate estimates of a worker's actual performance, one cannot rely solely on the global standards of organizations, but must carefully consider the specific factors of the work environment.

The linear regression model developed in this research proved its effectiveness in accurately predicting the performance of works outside the initial sample, thus validating its applicability in the Yanuncai parish under the conditions mentioned above. In this way, construction managers can use this model to anticipate the performance of their workers taking into account the working and climatic conditions and the skills of the workers.

Conclusions

- By collecting data from workers, it was shown that the linear regression model is able to accurately predict the performance that a worker can achieve in the mortar plastering activity, considering both internal and external factors.
- Analysis of actual worker performance revealed significant differences between theory and practice. While the theoretical standard performance set by the municipality follows a linear pattern and does not consider possible variations at the work site, the average performance calculated using the mathematical model consistently adjusts to these variations, suggesting greater accuracy in estimating actual performance.

- Although several internal and external factors can influence the final performance of workers, statistical analysis showed that only certain factors, including time, temperature, soil type, cover characteristics, level of difficulty, associated risks, work methods and worker skill, can effectively predict performance using linear regression.
- The mathematical model developed in this research offers the ability to predict the performance of labor in the placement of mortar plaster, taking into account multiple factors related to the works. This provides a greater capacity for planning execution times for managers of the construction sector in the city of Cuenca, specifically in Yanuncai. In addition, given the homogeneity of conditions in the provinces of Cuenca, there is the possibility that this model can be applied in other sectors of the same city with similar results.

Conflict of interest

There is no conflict of interest

Gratitude

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