Conciencia Digital
ISSN: 2600-5859
Vol. 7 No. 2, pp.6–27, April - June 2024
www.concienciadigital.org

Propuesta de modelo matemático del rendimiento de mano de obra en porcelanato en pisos. Caso de estudio: ciudad de Cuenca

Proposal for a mathematical model of labor performance in porcelain floors. Study case: Cuenca city

[1] Jorge Fabian Lucero Bonilla https://orcid.org/0009-0001-6891-8606
Master's Degree in Construction with a major in Construction Management, Catholic University of Cuenca, Cuenca, Ecuador.
jorge.lucero.01@est.ucacue.edu.ec
[2] Carlos Julio Castro Street https://orcid.org/0000-0002-6891-0030
Master's Degree in Construction with a Major in Sustainable Construction Management, Catholic University of Cuenca, Cuenca, Ecuador.
cjcallec@ucacue.edu.ec
[3] Nayra Mendoza Enriquez https://orcid.org/0000-0002-6673-2306
Co-tutor of the Master's degree in Construction with a Mention in Sustainable Construction Administration, Catholic University of Cuenca, Cuenca, Ecuador.
nayra.mendoza@ug.edu.ec

Scientific and Technological Research Article
Sent: 15/01/2024
Revised: 02/18/2024
Accepted: 04/03/2024
Published:05/04/2024
DOI:**https://doi.org/10.33262/concienciadigital.v7i2.2969**

Please quote: Lucero Bonilla, JF, Calle Castro, CJ, & Mendoza Enríquez, N. (2024). Proposal for a mathematical model of labor performance in porcelain flooring. Case study: city of Cuenca. ConcienciaDigital, 7(2), 6-27.https://doi.org/10.33262/concienciadigital.v7i2.2969

DIGITAL CONSCIOUSNESS, *and*It is a multidisciplinary, quarterly journal, which will be published electronically. Its mission is to contribute to the training of competent professionals with a humanistic and critical vision who are capable of presenting their research and scientific results to the same extent that their intervention promotes positive changes in society.https://concienciadigital.org
The journal is published by Editorial Ciencia Digital (a prestigious publisher registered with the Ecuadorian Book Chamber with membership number 663).www.celibro.org.ec

Palabras claves: Rendimiento, Mano de obra, Modelo matemático, Regresión lineal, Porcelanato

Resumen

Introducción. El rendimiento de mano de obra en la actividad de colocación de porcelanato en piso es clave para una eficiente planificación de proyectos constructivos. Sin embargo, aún hoy, la planificación de este rendimiento no se realiza de manera técnica y se asume la linealidad en los resultados, sin considerar la variabilidad de este rendimiento en función de factores externos e internos de los obreros. **Objetivo.** Proponer un modelo matemático para predecir el rendimiento de la mano de obra en la instalación de porcelanato en pisos en la ciudad de Cuenca, específicamente en la parroquia Machángara. **Metodología.** Se realizó una revisión de la literatura relacionada con los factores que influyen en el rendimiento de los obreros en esta actividad. A partir de esta información, se diseñó una ficha de observación que incluyó 6 variables y 35 indicadores relevantes. Se aplicó una metodología descriptiva de tipo correlacional con enfoque cuantitativo, recolectando datos de una muestra de 5 edificaciones en fase de colocación de porcelanato. **Resultados.** Los resultados, analizados estadísticamente, revelaron una eficacia del 98% del modelo propuesto en relación con el rendimiento real de los trabajadores. Además, se evidenció que, en Machángara, los rendimientos de los obreros se sitúan por debajo del estándar teórico proporcionado por el GAD de Cuenca. **Conclusión.** Se concluye que los modelos matemáticos basados en los factores estudiados son capaces de predecir con precisión el rendimiento de los obreros, lo que puede mejorar las predicciones y tiempos de ejecución de los gestores de obra.

Keywords: Yield, Labor, Mathematical model, Linear regression, Porcelain tile, Porcelain tiles

Abstract

Introduction. The labor performance in the activity of porcelain tile floor tile installation is key for an efficient planning of construction projects. However, even today, the planning of this performance is not carried out in a technical way and linearity is assumed in the results, without considering the variability of this performance as a function of external and internal factors of the workers. objective. To propose a mathematical model to predict the labor performance in the installation of porcelain tile floors in the city of Cuenca, specifically in the Machángara parish. Methodology. A review of the literature related to the factors that influence the performance of workers in this activity was carried out. Based on this information, an observation sheet was designed that included 6 variables and 35 relevant indicators. A descriptive methodology of a correlational type with a quantitative approach was applied, collecting data from a sample of 5 buildings in the porcelain tile installation phase. Results. The results, analyzed statistically, revealed an efficiency of 98% of the proposed model in relation to the current performance of the workers. In addition, it was evidenced that, in Machángara, the workers' performance is below the theoretical standard provided by the GAD of Cuenca. Conclusion. It is concluded that the mathematical models based on the factors studied are capable of accurately predicting the performance of the workers, which can improve the predictions and execution times of the site managers.

Introduction

TO the construction industry in Ecuador plays an important role in the country's economy, as it is a labor-intensive sector that attracts foreign direct investment and has a significant impact on the input supply sectors and financial institutions (Velástegui et al., 2022). In the future, an increase in construction activity is expected in this country, but with a new emphasis, which will be on efficiency, ensuring that projects are executed in the most optimal way possible, this means maximizing production and minimizing the waste of resources such as time, money, labor and materials (Díaz et al., 2022). In the construction sector, Ecuador continues to face various challenges in organization, education, government and culture that hinder the implementation of efficient approaches, particularly in terms of workforce performance, also known as Rendimiento de Mano de Trabajo or RMO (Fajardo and Quizhpe, 2021).

RMO refers to the work performed by workers within a specific period of time, taking into account the resources used, including time, effort, and materials and this measure is the basis for construction management as it provides a way to assess the effectiveness and productivity of work activities on the jobsite (Manoharan et al., 2022). Understanding job performance is a pillar for construction managers and contractors as it allows them to plan, allocate resources, and budget effectively, while supporting the optimization of work processes and identifying areas for improvement, they can make informed decisions to improve efficiency and profitability (Assaad et al., 2022).

Despite the aforementioned advantages, the construction industry in Ecuador constantly faces difficulties related to a low ROI of its workers. This problem arises from a combination of multifaceted factors that include the work environment, contractual conditions and modalities, economic considerations, cultural and environmental aspects, among others (Santisteban and Silva, 2022). These elements influence the worker's ability to perform their tasks within the stipulated time and since the efficiency of the productive system in the construction industry is closely linked to its human resources, the lack of actions or measures related to the worker's work environment to ensure optimal performance represents a significant obstacle to achieving project objectives (Momade et al., 2023).

In the construction industry, there is a common strategy used to forecast the expected performance of a worker during a project. This strategy can be considered as a theoretical RMO, which measures the amount of work (m2) that is expected to be performed within a specific period of time, usually by hours or days, following established protocols. This theoretical value is determined by organizations, unions or government agencies in each country based on the performance history of each construction activity available in their database and the experience of professionals in the field (Hamza et al., 2022). However, there are discrepancies between the actual execution of the works and the information documented in the technical files, this is because the actual RMO can be influenced by several project-specific factors, which can affect the continuity of performance and hinder the initial estimate provided by the project managers (Aguilar et al., 2013; Van et al., 2021).

One of the construction activities most affected by this lack of continuity in the RMO is the placement of porcelain tiles, because, although there is an Ecuadorian performance standard determined by the ANDENCE Precast Concrete Industry which is 30m2/day, the reality is that, on many occasions, this performance is not achieved (Fajardo and Quizhpe, 2021). Porcelain is a covering for floors and walls, with low thickness (8 to 12mm), with extraordinary technical presentations and varied decorative possibilities, it is a very compact mass with excellent mechanical and chemical properties, it is classified as the evolution of glazed ceramics, but more resistant, much more durable and with little absorption, It can be installed anywhere, both indoors and outdoors (Herrera et al., 2023). The placement of porcelain tiles involves a series of processes, ranging from surface preparation to sealing joints, using specific adhesives. Each step requires precision and efficiency, and any disturbance, both internal and external, can affect the final performance. Therefore, the activity demands meticulous coordination and careful management to ensure optimal results (Alves et al., 2023).

A common strategy often employed in the Ecuadorian field to achieve favorable results in the installation of porcelain tiles is the constant supervision provided by the person in charge. This ensures that the procedures for the preparation and manufacture of the materials are followed meticulously, according to their place of origin. In addition, an inspector is usually designated with the power to reject poor quality materials or stop the project if deemed necessary. However, supervising this activity is only one aspect to consider. Currently, there are additional factors that can impact the performance of workers, which are not commonly used in the professional and organizational field to ensure optimal performance (Guzmán, 2012; Salgado, 2016).

An industry expert who delves deeper into the factors that impact job performance is Luis Fernando Botero through his work, "Analysis of performance and labor consumption in construction activities," which provides valuable information in this area. The author highlights the presence of 7 factors that should be taken into account. The first factor to consider is the general state of the economy, this includes factors such as the availability of qualified workers, experienced supervisors, and essential materials needed for the construction project. Another important factor to consider is labor aspects, which encompass various elements such as working conditions, schedules, breaks, incentives, and more. The third is climatic factors such as temperature, soil conditions, and the possibility of working indoors, which can affect worker performance.

The fourth factor has to do with the activity itself, including its unique characteristics such as complexity, execution times, available resources, and the overall work environment. Here is a summary of the equipment needed to do the job right: the right tools and equipment, keeping them in good condition, regular maintenance, ensuring timely supply, and using personal protective equipment to prioritize safety. Supervision plays a crucial role in ensuring that construction activities are carried out with maximum efficiency and effectiveness. It involves having experienced supervisors who possess the necessary skills to guide and control the process. Finally, worker conditions are crucial factors that directly impact their performance on the job. These conditions encompass aspects such as training, experience, motivation, and working conditions (Botero, 2021).

Based on the above, the objective of this research is to propose a mathematical model that facilitates the prediction of labor performance in the porcelain tile installation activity in the city of Cuenca, Ecuador, specifically in the Machángara parish. The purpose of this proposal is to provide construction managers in this sector with a tool to plan the execution times of their projects based on the expected labor performance, considering the various factors related to the porcelain tile installation activity.

In the first stage of the research, the factors that may influence the RMO in the porcelain tile installation activity are identified, based on the bibliographic review. Then, an observation sheet is prepared, which is applied in various works in Machángara to evaluate these factors together with the actual performance of the workers. Subsequently, the data collected is analyzed using a statistical program to determine the influence of these factors on the performance of the workers and thus develop the mathematical model.

ISSN: 2600-5859
Vol. 7 No. 2, pp.6–27, April - June 2024
www.concienciadigital.org

In the second stage, the mathematical model is applied to a set of 5 works in Machángara to compare the calculated average performance with the actual performance of the workers. In addition, the theoretical or standard performance provided by the Decentralized Autonomous Government (GAD) of the city of Cuenca is used to verify possible variations compared to the standard used in the city.

Methodology

The methodological approach of this study is centered on a correlational-descriptive analysis. Its objective is to examine how a variety of factors, both internal and external, can affect the performance of workers during the placement of porcelain tiles, a process with a defined sequence that includes cleaning the work area, applying binding additives, preparing the mortar, settling the porcelain tiles, leveling, and using spacers or spacers. Through this methodology, we sought to describe the significant results of these relationships in order to identify the most influential factors in this activity.

The research universe comprised 1 and 2-story construction projects registered in the GAD of Cuenca at the time of carrying out this study. The target population was limited to the projects in progress in the Machángara parish. Since most of these projects had already completed the porcelain tile installation phase on floors at the time of data collection, it was decided to carry out a non-probabilistic sampling, specifically a convenience sampling. This involved selecting 5 buildings that were in the porcelain tile installation stage during the data collection period, thus representing the sample for the study. The characteristics of the projects and the crews used in the research are mentioned below.

Table 1

Independent variables and indicators

Edification	Guy	Gang	Workers	Occupational structure	Daily salary for each teacher
E1	Two floors	Squad 1 (C1)	3 teachers	C2	35 dollars
			2 officers	E2	22 dollars
		Squad 2 (C2)	3 teachers	C2	35 dollars
			2 officers	E2	22 dollars
E2	Two floors	Squad 1 (C1)	3 teachers	C2	35 dollars
			2 officers	E2	22 dollars
		Squad 2 (C2)	3 teachers	C2	35 dollars
			2 officers	E2	22 dollars
E3	Two floors	Squad 1 (C1)	3 teachers	C2	35 dollars
			2 officers	E2	22 dollars
		Squad 2 (C2)	3 teachers	C2	35 dollars
			2 officers	E2	22 dollars
E4	A flat		3 teachers	C2	35 dollars

		Squad 1 (C1)	2 officers	E2	22 dollars
E5	A flat	Squad 1 (C1)	2 teachers 2 officers	C2 E2	35 dollars 22 dollars

To collect data from the 39 workers in the 5 previously mentioned works, an observation form was used, which was implemented in the field by the researcher. This form was based on the independent variables and indicators proposed by Botero (2002), who defines performance as a multidimensional conjunction of conditions: climate, activity, equipment, supervision and the worker's own conditions. These factors, taken together, can enhance or reduce a worker's performance, depending on the nature of their tasks and the work environment during data collection. The variables and indicators are shown in Table 2.

Table 2

Independent variables and indicators

Variable	Dimensions	Indicators and their numerical equivalence				
		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
	Difficulty	Difficult		Normal		Easy
	Danger	Dangerous	Risky	Normal	Moderate	No danger
	Interruptions	≥ 1 hour	15≥60 min	5≥15 min	0≥5 min	None

Table 2

Independent variables and indicators (continued)

Variable	Dimensions	Indicators and their numerical equivalence				
		1	2	3	4	5
Activity	Order and cleanliness	Difficult access	Rubbish	Passable	Little dirt	Total cleanliness and order
	Previous activities	Repeat	A lot of healing	Little healing	Acceptable	Perfect
	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
Equipment	Tool	Inadequate		Adequate		Special
	Equipment	Inadequate		Adequate		Special
	Maintenance	Null		Acceptable		Well
	Supply	Never		Sometimes		Always

	Protective element	None		Almost all		All
	Address (acceptance criteria)	None	Informal	Verbal	Previous verbals	Under written
	Instruction	None		Verbal - required		Required document
	Follow-up	No review		Eventual review		Always
Supervision	Supervisor (Teacher)	Bad		Regular		Well
	Quality Assurance	It does not exist	Isolated efforts	Inventory	In progress	ISO Certificate
	Personal situation	Neurotic	Sad	Normal	Good	Excellent
	Work pace	Slow		Normal		Fast
	Health	Sick		Normal		Excellent
Worker	Ability	Inexperienced		Skilled		Expert
	Training	None	Apprentice	Required	Expert	Certificate
	Contract	Administration				Outsourcing
	Union	Yeah				No
Labor	Incentives	No				Yeah
	Salary	SMLV				≥SMLV

*Note.*This table was adapted from Botero (2002). Prepared by: Authors

As can be seen in Table 2, the operationalization of the variables proposed by Botero is qualitative. However, in this research, the analysis of the information is quantitative. Therefore, the indicators have been translated from qualitative terms to numbers. An example of this process is presented in Table 3, where the indicators of the "Time" dimension have been replaced by numbers from 1 to 5. In this scale, the value 1 represents the least favorable condition, while the value 5 represents the most favorable condition of the dimension.

Table 3

Independent variables and indicators

Variable	**Dimension**	**Indicators**	**Transposition of terms**
		Storm	1
		Downpour	2
Climate	Time	Drizzle	3
		Cloudy	4
		Clear	5

Table 4 below shows the data collected from the 39 workers at the 5 works analysed, with their indicators expressed numerically based on Table 2, and the actual performance obtained at the end of the day. This performance was calculated by dividing the total number of m2 of porcelain tiles placed in an 8-hour workday. An example of this is the performance of worker 1 (O1), who is a master bricklayer who placed a total of 1.6 m2 of porcelain tiles at the end of the day. This value was divided for the 8-hour workday and gave a total performance of 0.2 m2/hour. This same procedure was followed for the other workers.

Table 4

Data collection form

Edification	Gang	Worker	Time	Temperature	Floor	Deck	Difficulty	Danger	Continuity	Order and cleanliness	Work base	Typicality	Block	Tool	Equipment	Maintenance	Supply	Protective element	Address	Instruction	Follow-up	Calif. Master	Aserg. Quality	Personal Sit.	Fatigue	Ability	Knowledge	Training	Actual performance (m2/hour)
		O1	4	2	4	4	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.2
		O2	3	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.18
	C 1	O3	4	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.2
		O4	3	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.18
		O5	4	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.2
E1		O6	3	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.18
		O7	4	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.2
	C 2	O8	3	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.18
		O9	4	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.2
		O10	3	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.18
		O11	4	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.2
		O12	3	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.18
E2	C 1	O13	4	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.2
		O14	3	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.18
		O15	4	2	4	5	3	3	3	3	5	5	5	3	3	2	3	1	3	2	2	3	2	4	3	4	3	2	0.2

Conciencia Digital

ISSN: 2600-5859
Vol. 7 No. 2, pp.6–27, April - June 2024

www.concienciadigital.org

Table 4

Data collection form (continued)

Edification	Gang	Worker	Time	Temperature	Floor	Deck	Difficulty	Danger	Continuity	Order and cleanliness	Work base	Typicality	Block	Tool	Equipment	Maintenance	Supply	Protective element	Address	Instruction	Follow-up	Calif. Master	Aserg. Quality	Personal Sit.	Fatigue	Ability	Knowledge	Training	Actual performance (m2/hour)
		O16	4	3	3	4	3	2	4	4	4	4	4	3	3	3	4	2	3	3	3	4	3	3	3	3	3	3	0.13
		O17	3	3	3	4	3	2	4	4	4	4	4	3	3	3	4	2	3	3	3	4	3	3	3	3	3	3	0.13
	C 2	O18	4	3	3	4	3	2	4	4	4	4	4	3	3	3	4	2	3	3	3	4	3	3	3	3	3	3	0.13
		O19	3	3	3	4	3	2	4	4	4	4	4	3	3	3	4	2	3	3	3	4	3	3	3	3	3	3	0.13
		O20	4	3	3	4	3	2	4	4	4	4	4	3	3	3	4	2	3	3	3	4	3	3	3	3	3	3	0.13
		O21	3	3	3	4	3	2	4	4	4	4	4	3	3	3	4	2	3	3	3	4	3	3	3	3	3	3	0.13
		O22	4	3	3	4	3	2	4	4	4	4	4	3	3	3	4	2	3	3	3	4	3	3	3	3	3	3	0.13
	C 1	O23	4	3	3	5	4	4	3	3	5	5	5	4	4	3	4	3	4	4	4	4	4	3	3	4	4	3	0.22
		O24	3	3	3	5	4	4	3	3	5	5	5	4	4	3	4	3	4	4	4	4	4	3	3	4	4	3	0.21
E3		O25	4	3	3	5	4	4	3	3	5	5	5	4	4	3	4	3	4	4	4	4	4	3	3	4	4	3	0.22
		O26	3	3	3	5	4	4	3	3	5	5	5	4	4	3	4	3	4	4	4	4	4	3	3	4	4	3	0.21
		O27	4	3	3	5	4	4	3	3	5	5	5	4	4	3	4	3	4	4	4	4	4	3	3	4	4	3	0.22
	C 2	O28	3	3	3	5	4	4	3	3	5	5	5	4	4	3	4	3	4	4	4	4	4	3	3	4	4	3	0.21
		O29	4	3	3	5	4	4	3	3	5	5	5	4	4	3	4	3	4	4	4	4	4	3	3	4	4	3	0.22
		O30	3	3	3	5	4	4	3	3	5	5	5	4	4	3	4	3	4	4	4	4	4	3	3	4	4	3	0.21
		O31	4	3	3	5	4	4	3	3	5	5	5	4	4	3	4	3	4	4	4	4	4	3	3	4	4	3	0.22
		O32	3	3	3	5	4	4	3	3	5	5	5	4	4	3	4	3	4	4	4	4	4	3	3	4	4	3	0.21
E4	C 1	O33	4	3	4	4	4	3	3	3	5	5	5	4	4	3	4	2	3	3	3	4	3	3	4	4	3	3	0.18
		O34	3	3	4	4	4	3	3	3	5	5	5	4	4	3	4	2	3	3	3	4	3	3	4	4	3	3	0.16
		O35	4	3	4	4	4	3	3	3	5	5	5	4	4	3	4	2	3	3	3	4	3	3	4	4	3	3	0.18
		O36	3	3	4	4	4	3	3	3	5	5	5	4	4	3	4	2	3	3	3	4	3	3	4	4	3	3	0.16
E5	C 1	O37	4	3	4	4	4	3	3	3	5	5	5	4	4	3	4	2	3	3	3	4	3	3	4	4	3	3	0.18
		O38	3	3	4	4	4	3	3	3	5	5	5	4	4	3	4	2	3	3	3	4	3	3	4	4	3	3	0.16
		O39	4	3	4	4	4	3	3	3	5	5	5	4	4	3	4	2	3	3	3	4	3	3	4	4	3	3	0.18

The data were subjected to normality tests to assess their distribution and determine the most appropriate statistical treatment technique. In this case, the statistical program uses a test called Shapiro-Wilk to assess the distribution and homogeneity of the data. It calculates the P-Value, which has a standardized threshold of 0.05 and a defined criterion. Any number above this threshold indicates a normal distribution, while a lower number suggests that the data do not meet the assumptions of normality.

Kruskal-Wallis analysis was performed to assess the presence of a significant association between categorical data sets. This analysis involves the calculation of the chi-square (χ^2)

value. Within this particular context, degrees of freedom (df) signify the number of independent variables that can be modified without affecting the predetermined restrictions of the analysis. The significance level (p) is a pre-established threshold used to determine whether the findings of a study are statistically significant or could be attributed to chance.

After the analysis, linear regression is employed, using fit measures such as the linear correlation coefficient (R) and the coefficient of determination (R^2). These measures represent the intensity and fraction of variability accounted for by the model, respectively. In addition, metrics such as the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the root mean square error (RMSE) are employed to assess the quality of the model. These metrics are minimized to determine the suitability and predictive ability of the model for the analyzed data and proceed with the calculation of the model coefficients.

When calculating the model coefficients, crucial elements are discerned, including the value of the estimator, which indicates the relationship between the independent and dependent variables. The SE coefficient measures the precision of this estimate, while the t coefficient assesses whether this number deviates significantly from zero. The p coefficient provides a measure of the probability of finding this correlation if there is no true association between the variables.

Once the coefficients are obtained, the general formula of the mathematical model is derived using linear regression. The formula of the linear regression model is composed of the variable of interest (y) as the dependent variable, and multiple independent variables (X1, X2,...,Xn). The independent term (b0) indicates the expected value of y when all independent variables are zero. The coefficients (b1, b2,...,bn) measure the change in y for each unit change in the respective independent variables, keeping the others constant. Each coefficient provides information about the specific influence of the corresponding independent variable on the dependent variable and is presented below:

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

Results

The statistical analysis performed using the Shapiro-Wilk test yielded significant results, with a p value less than 0.001 for all variables evaluated. The results unequivocally demonstrate that the data collected, relating to the different working circumstances and performance parameters in the context of porcelain tile placement, deviate from a normal distribution.

Due to the non-normal distribution of the data, a Kruskal-Wallis analysis was performed. This analysis revealed substantial disparities in performance across the porcelain setting activity under the various working circumstances tested. The test reveals a highly significant statistical result ($p < 0.001$) for all variables examined. This implies that at least one of the working circumstances evaluated has a substantial influence on the performance of the workers.

As can be seen in Table 5, the working conditions such as Time, Temperature, Floor, Cover, Difficulty, Danger, Continuity, Order and Cleanliness, Work Base, Typicality, Cut, Tool, Equipment, Maintenance, Supply, Protective Element, Direction, Instruction, Monitoring, Master Qualification, Quality Assurance, Personal Sit., Fatigue, Skill, Knowledge and Training, all show a significant variation in their influence on the performance of the workers in the placement of porcelain tiles.

Table 5

Independent variables and indicators

Variable	χ^2	p
Time	21.3	< .001
Temperature	27.5	< .001
Floor	38.0	< .001
Deck	23.9	< .001
Difficulty	27.9	< .001
Danger	38.0	< .001
Continuity	38.0	< .001
Order and cleanliness	38.0	< .001
Work base	38.0	< .001
Typicality	38.0	< .001
Block	38.0	< .001
Tool	27.9	< .001
Equipment	27.9	< .001
Maintenance	27.5	< .001
Supply	27.5	< .001
Protective element	33.3	< .001
Address	38.0	< .001
Instruction	33.3	< .001

Table 5

Independent variables and indicators (continued)

Variable	χ^2	p
Follow-up	33.3	< .001
Calif. Master	27.5	< .001
Aserg. Quality	33.3	< .001
Personal Sit.	27.5	< .001
Fatigue	21.2	< .001
Ability	38.0	< .001
Knowledge	38.0	< .001
Training	27.5	< .001

Source: own elaboration

After the Kruskal-Wallis analysis, the mathematical model was built through a multiple linear regression of a factor (yield) in which, through the model's adjustment measures, it was possible to identify that only 5 factors: time, temperature, soil, cover and difficulty can be used in the model, this is because the other variables present a problem of singularity or confusion in the linear regression model. This phenomenon suggests a possible linear relationship or redundancy between some predictor variables, making it difficult for the model to accurately estimate the effects of said variables on the dependent variable, which is why they were discarded.

After making the necessary adjustments, the mathematical model was built using the 5 specified factors. A test of the model fit measures was then performed. The data presented in Table 6 clearly demonstrate a strong correlation (R = 0.992) between the variables, suggesting a reliable and significant link. The high adjusted coefficient of determination (R^2 = 0.981) suggests that about 98.1% of the fluctuations in the dependent variable can be explained by the independent variables, indicating a strong model fit. The AIC and BIC criteria exhibit negative values very close to zero (-310 and -298 respectively), indicating a robust model fit. Furthermore, the model predictions demonstrate significant accuracy, as evidenced by the low value of the root mean square error (RMSE = 0.00380).

Table 6

Model fit measures

Model	R	Corrected R^2	AIC	BIC	RMSE
1	*0.992*	*0.981*	*-310*	*-298*	*0.00380*

After thoroughly checking the accuracy and reliability of the numbers used, the coefficients of the model are calculated. Table 7 shows that time, temperature and soil have remarkable estimators ($p < 0.001$), suggesting a substantial impact on yield. It is clear that there is a positive correlation between time (Estimator = 0.01371) and yield, indicating that favorable weather conditions result in an increase in yield.

In contrast, there is a negative correlation between temperature (Estimator = -0.11182) and soil (Estimator = -0.04769) with yield, indicating that an increase in temperature or soil type is linked to a drop in production. However, the variable “Cover” does not seem to exert a substantial impact ($p = 0.473$) on performance, as evidenced by its high p-value. This suggests that there is insufficient data to support the idea that it genuinely affects performance. The variable “Difficulty” shows a notable and favourable impact (Estimator = 0.08912), suggesting that an escalation in difficulty is linked to an increase in yield.

Table 7

Model coefficients - performance

Predictor	Estimator	EE	t	p
Constant	0.30477	0.04462	6.830	< .001
Time	0.01371	0.00135	10.194	< .001
Temperature	-0.11182	0.00880	-12.713	< .001
Floor	-0.04769	0.00477	-9.999	< .001
Deck	-0.00314	0.00433	-0.726	0.473
Difficulty	0.08912	0.00477	18.684	< .001

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

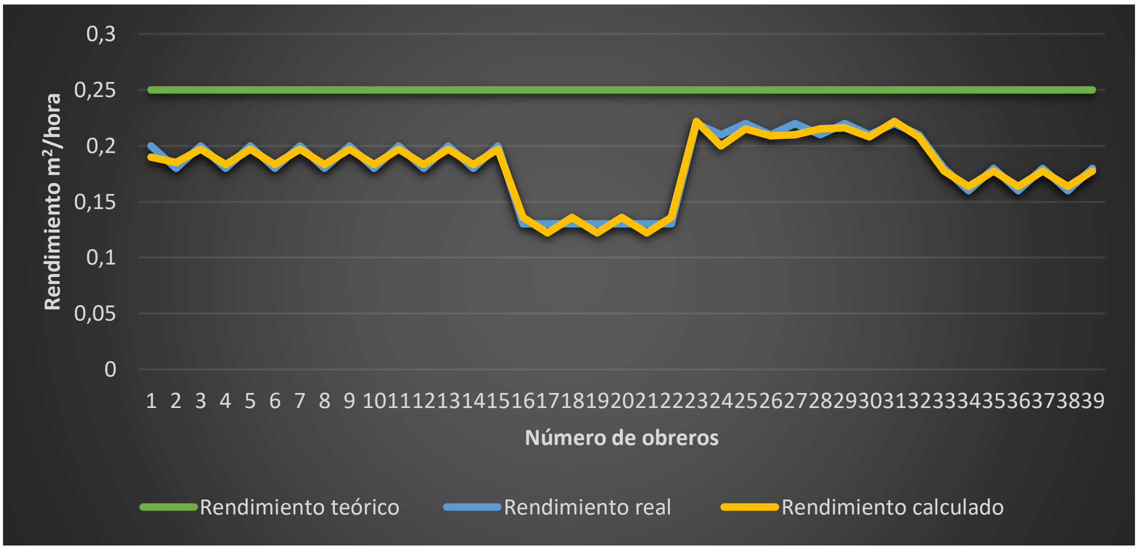
$$y = 0.30477 + 0.01371*Time - 0.11182*Temperature - 0.04769*Soil - 0.00314*Cover + 0.08912*difficulty$$

To demonstrate the effectiveness of the model to predict the performance within the sample of works, the average performances are calculated with the mathematical model and compared with the actual performance of the workers. Also included in this comparison is the theoretical performance provided by the Cuenca GAD for the placement of porcelain tiles, which is 0.25 m2/hour.

Conciencia Digital
ISSN: 2600-5859
Vol. 7 No. 2, pp.6–27, April - June 2024
www.concienciadigital.org

Figure 1.

Comparison of actual, theoretical and average performance calculated with the mathematical model



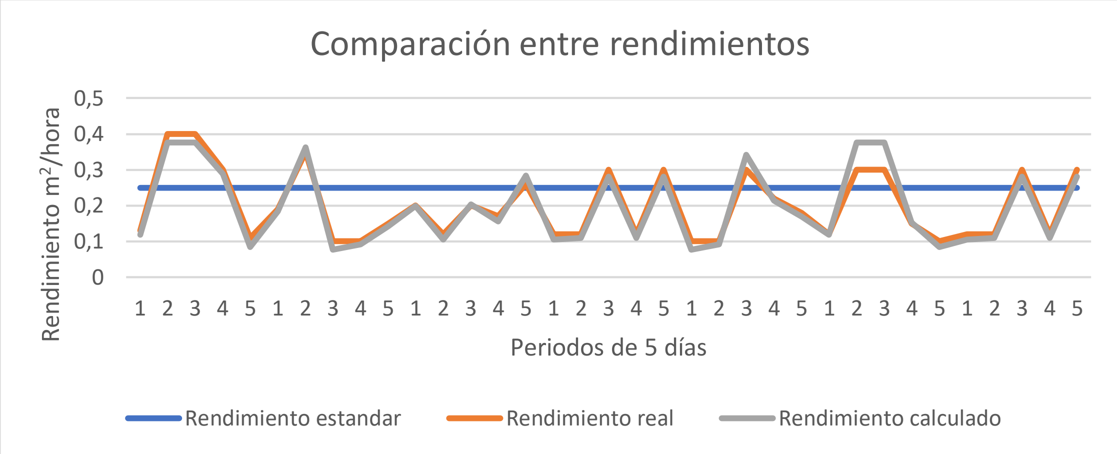
Source: Own elaboration

The comparison between the actual and theoretical performance, as shown in Figure 1, reveals significant differences. During data collection, the study sample never reaches 0.25 m2/hour and remains consistently below this value, with variations depending on each worker. However, the mathematical model demonstrates a remarkable ability to accurately approximate the actual performance of the sample, effectively adapting to the fluctuations observed based on the factors analysed.

In order to verify the applicability and accuracy of the mathematical model beyond the initial sample used for its development, a new data collection was carried out in 5 construction sites during the ceramic tile placement stage. One worker was randomly selected from each construction site to be analyzed for 5 working days. As illustrated in Figure 2, on this occasion, the workers even managed to exceed the theoretical performance established by the Cuenca GAD, although this performance fluctuated over the days. On the other hand, the mathematical model demonstrated an accurate capacity to predict the actual performance of the workers based on the factors analyzed, which allowed it to effectively adapt to these temporal variations.

Figure 2.

Comparison of actual, theoretical and average performance calculated with the mathematical model



Source: Own elaboration

Table 8 below shows the values for time, temperature, soil type, cover conditions and level of difficulty experienced by the workers during data collection. In addition, the standard or theoretical yield, the actual yield and the average yield calculated using the mathematical model are presented.

Table 8

Comparison of performance of new works

Denomination	Day	Time	Temperature	Floor	Deck	Difficulty	Standard Performance (m2/hour)	Actual performance (m2/hour)	Calculated performance(m2/hour)
Teacher 1	1	3	3	3	5	3	0.25	0.13	0.12
	2	2	1	2	5	3	0.25	0.4	0.38
	3	2	1	2	5	3	0.25	0.4	0.38

Conciencia Digital
ISSN: 2600-5859
Vol. 7 No. 2, pp.6–27, April - June 2024
www.concienciadigital.org

Table 8

Comparison of performance of new works (continued)

Denomination	Day	Time	Temperature	Floor	Deck	Difficulty	Standard Performance	Actual performance (m2/hour)	Calculated performance(m2/hour)
Teacher 1	4	4	2	4	4	4	0.25	0.3	0.29
	5	4	3	4	5	3	0.25	0.11	0.09
Master 2	1	1	1	2	5	1	0.25	0.19	0.18
	2	1	1	2	5	3	0.25	0.35	0.36
	3	3	3	4	3	3	0.25	0.1	0.08
	4	4	3	4	3	3	0.25	0.1	0.09
	5	3	2	5	3	3	0.25	0.15	0.14
Master 3	1	2	1	2	5	1	0.25	0.2	0.20
	2	5	3	4	3	3	0.25	0.12	0.11
	3	4	2	4	3	3	0.25	0.2	0.20
	4	5	3	3	2	3	0.25	0.17	0.16
	5	5	3	4	3	5	0.25	0.26	0.28
Master 4	1	5	3	4	3	3	0.25	0.12	0.11
	2	5	1	5	1	1	0.25	0.12	0.11
	3	5	1	5	3	3	0.25	0.3	0.28
	4	5	1	5	1	1	0.25	0.12	0.11
	5	5	1	5	3	3	0.25	0.3	0.28
Master 5	1	3	3	4	3	3	0.25	0.1	0.08
	2	4	3	4	3	3	0.25	0.1	0.09
	3	3	1	3	5	3	0.25	0.3	0.34
	4	5	2	4	4	3	0.25	0.22	0.21
	5	5	2	5	3	3	0.25	0.18	0.17
Master 6	1	3	3	3	5	3	0.25	0.12	0.12
	2	2	1	2	5	3	0.25	0.3	0.38
	3	2	1	2	5	3	0.25	0.3	0.38
	4	5	3	3	3	3	0.25	0.15	0.15
	5	4	3	4	5	3	0.25	0.1	0.09
Master 7	1	5	3	4	3	3	0.25	0.12	0.11
	2	5	1	5	1	1	0.25	0.12	0.11
	3	5	1	5	3	3	0.25	0.3	0.28
	4	5	1	5	1	1	0.25	0.12	0.11
	5	5	1	5	3	3	0.25	0.3	0.28

Discussion

Regarding the factors that affect labor performance when installing porcelain tiles on floors, it was found that all the aspects considered in this study have the capacity to influence the final performance. However, not all of these factors together are capable of accurately predicting the performance obtained by a worker in this activity. Within the framework of this research, it was shown that only climatic variables and those related to the activity itself have this predictive capacity, particularly those associated with time, temperature, soil conditions, the presence of roofing and the complexity of the task.

Although the theoretical performance provided by the Decentralized Autonomous Government of the city of Cuenca serves as a conceptual reference point for predicting the performance of workers in the installation of porcelain tiles, it has been shown that, at least in the Machángara parish, these performances exhibit a constant fluctuation. In most cases, the data collected fail to reach this established theoretical performance. This situation can have a significant impact on the planning of construction managers, since, if they base their estimates of project completion time on theoretical performance, it is likely that this deadline will not be met due to discrepancies between theoretical expectations and the reality observed on the ground.

The average performance calculated using the mathematical model proved to be effective in predicting variations in labor performance, particularly in relation to climatic variables and those associated with the activity itself. This finding underlines the considerable applicability of linear regression in the construction field. Construction managers now have the ability to anticipate the performance of workers based solely on weather forecasts and the level of risk perceived by workers during the months of project execution. This allows them to make more precise plans and avoid possible breaches of delivery deadlines, at least as regards this specific construction activity.

Conclusions

- The actual performance of workers in the porcelain floor installation activity differs from the theoretical performance of the Cuenca GAD in the Machángara Parish because it fluctuates from day to day and in many cases remains below the standard performance.
- The mathematical model based on the application of linear regression achieved 98% efficiency in predicting the actual performance of workers in the placement of porcelain tiles; however, this prediction is conditioned only by factors of: time, temperature, soil, roof and difficulty.
- An important limitation of this research lies in the fact that only buildings located in the Machángara parish of the city of Cuenca were used as a sample. This limitation was due to the unavailability of data or resources to include works from

the entire city of Cuenca. As a result, the findings and conclusions obtained may not be completely representative of the situation throughout the city, limiting the generalization of the results to a broader context.

- In future research, it would be advisable to expand the sample to include a greater variety of constructions in different areas of the city, which would allow a more complete and representative evaluation of the performance of the workforce in the porcelain tile installation activity.

Gratitude

This article is part of the research and graduation work of the Master's Program in Construction with a Mention in Sustainable Construction Administration of the Catholic University of Cuenca, therefore we thank each and every one of the instructors belonging to the research groups; City, Environment, and Technology (CAT), and Embedded systems and artificial vision in sciences, Architectures, Agriculture, Environment and Automation (SEVA4CA), for the knowledge and information provided for the preparation of the work.

Conflict of interest

There is no conflict of interest

Bibliographic references

Aguilar Pallarès, A., Morante Barragán, JF, Novelle Rodríguez, M., and Subirana Domènech, M. (2013). Electronic control devices: What is known? what is unknown? Forensic Medicine Notebooks, 19(3-4), 75-86. https://doi.org/10.4321/S1135-76062013000200003

Alves, CL, Skorych, V., De Noni, A., Hotza, D., Gómez González, SY, Heinrich, S., and Dosta, M. (2023). Improving the sustainability of porcelain tile manufacturing by flowsheet simulation. Ceramics International, 49(14, Part B), 24581-24597. https://doi.org/10.1016/j.ceramint.2023.01.056

Assaad, R., El-adaway, I., Hastak, M., and Needy, K. (2022). Key Factors Affecting Labor Productivity in Offsite Construction Projects. Journal of Construction Engineering and Management, 149, 04022158. https://doi.org/10.1061/JCEMD4.COENG-12654

Botero, LFB (2021). Principles, tools and implementation of Lean Construction. EAFIT University.

Díaz-Kovalenko, I.E., Larrea-Rosas, K.P., & Barros-Naranjo, J. (2022). The construction sector in the Ecuadorian economy, importance and perspectives.

Social and Economic Sciences, 6(2), Article 2. https://doi.org/10.18779/csye.v6i2.598

Fajardo Guapisaca, WM, and Quizhpe Campoverde, JD (2021). Determination of factors that affect labor performance in the ceramic tile installation activity in the city of Cuenca. Dominio de las Ciencias, 7(Extra 4), 138. https://dialnet.unirioja.es/servlet/articulo?codigo=8383979

Guzmán, A. (2012). ITIL v3—IT Service Management. Ecorfan Journal, 3(7), 801-806. https://dialnet.unirioja.es/servlet/articulo?codigo=4001967

Hamza, M., Shahid, S., Bin Hainin, M.R., and Nashwan, M.S. (2022). Construction labor productivity: Review of factors identified. International Journal of Construction Management, 22(3), 413-425. https://doi.org/10.1080/15623599.2019.1627503

Manoharan, K., Dissanayake, P., Pathirana, C., Deegahawature, D., and Silva, R. (2022). Assessing the performance and productivity of labor in building construction projects through the application of work-based training practices. Construction Innovation, ahead-of-print. https://doi.org/10.1108/CI-05-2022-0126

Momade, M.H., Shahid, S., Falah, G., Syamsunur, D., and Estrella, D. (2023). Review of construction labor productivity factors from a geographical standpoint. International Journal of Construction Management, 23(4), 697-707. https://doi.org/10.1080/15623599.2021.1917285

Salgado Altamirano, JR (2016). Business plan for the creation of a company dedicated to the design, decoration and finishing of wood construction in the city of Quito [bachelorThesis, Quito: Universidad de las Américas, 2016]. http://dspace.udla.edu.ec/handle/33000/5295

Santisteban Rimaycuna, DM, and Silva Coronado, S. del R. (2022). Design of a logistics management system for sales in the Bim SAC corporation, José Leonardo Ortiz 2018. Institutional Repository - USS. http://repositorio.uss.edu.pe//handle/20.500.12802/9319

Van Tam, N., Quoc Toan, N., Tuan Hai, D., and Le Dinh Quy, N. (2021). Critical factors affecting construction labor productivity: A comparison between perceptions of project managers and contractors. Cogent Business and Management, 8(1), 1863303. https://doi.org/10.1080/23311975.2020.1863303

Velástegui, AMY, Franco, MLL, León, LS, and Cumbicos, JGN (2022). The contribution of the construction sector to the gross domestic product GDP in

Ecuador1. Lasallista Research Journal, 15(2), 286-299.
https://www.redalyc.org/journal/695/69559233023/html/

Indexaciones