ISSN: 2600-5859
Vol. 7 No. 1.3, pp.91–112, March 2024

www.concienciadigital.org

Rendimiento de mano de obra en cielo raso. Caso de estudio: ciudad de Cuenca

Labor performance in ceiling. Study case: Cuenca city

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Scientific and Technological Research Article
Sent: 12/15/2023
Revised: 18/01/2024
Accepted: 02/08/2024
Published:05/03/2024
DOI:**https://doi.org/10.33262/concienciadigital.v7i1.3.2940**

Please quote: Zhicay Arbito, J.L., Calle Castro, C.J., & Mendoza Enríquez, N. (2024). Labor performance in suspended ceilings. Case study: city of Cuenca. ConcienciaDigital, 7(1.3), 91-112.https://doi.org/10.33262/concienciadigital.v7i1.3.2940

DIGITAL CONSCIOUSNESS,andIt 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

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Palabras claves: Rendimiento de mano de obra, Cielo raso, Modelo matemático, Regresión lineal, Proyección de rendimiento.

Resumen

Introducción. La colocación de cielo raso es una tarea esencial en la construcción, cuyos rendimientos son clave para la planificación y ejecución eficientes de proyectos. Sin embargo, los enfoques actuales de predicción del rendimiento en esta actividad a menudo son simplistas al asumir una linealidad en los resultados, sin considerar la variabilidad inherente en el desempeño de los obreros. **Objetivo.** El objetivo primordial de este estudio es la creación de un modelo matemático eficiente para proyectar el rendimiento de la mano de obra en proyectos de instalación de cielo raso en la ciudad de Cuenca, particularmente en la parroquia San Sebastián. **Metodología.** Se implementó una metodología de enfoque relacional-descriptivo con un enfoque cuantitativo. Se inició con una exhaustiva revisión de la literatura para identificar los posibles factores que podrían influir en el rendimiento de la mano de obra. Con esta información, se diseñó una ficha de observación que se aplicó a 45 trabajadores en seis diferentes sitios de construcción dentro de la zona de estudio. Los datos recopilados fueron analizados mediante un software estadístico para establecer un modelo matemático que permitiera predecir el rendimiento de los obreros en función de los factores identificados. Posteriormente, se compararon estos valores con el rendimiento real y teórico obtenido. **Resultados.** Uno de los hallazgos más destacados fue la notable diferencia entre el rendimiento real de los obreros y el rendimiento teórico, indicando que el rendimiento no sigue una tendencia lineal en el tiempo y varía en función de diversos factores como las condiciones climáticas, el equipo utilizado, la supervisión y las características individuales del trabajador. **Conclusión.** El modelo matemático desarrollado en esta investigación demostró ser eficaz para prever el rendimiento de los obreros en base a los factores analizados. **Área de estudio general:** Ingeniería, Industria y Construcción. **Área de estudio específica:** Administración de la Construcción

Keywords: Labor performance, Ceiling, Mathematical

Abstract

Introduction. Ceiling installation is an essential task in construction, whose performance is key to efficient project planning and execution. However, current approaches to predicting performance in this activity are often simplistic in that

model, Linear regression, Performance projection.

they assume linearity in results, without considering the inherent variability in worker performance. objective. The main objective of this study is the creation of an efficient mathematical model to project labor performance in ceiling installation projects in the city of Cuenca, particularly in the San Sebastian parish. Methodology. A relational-descriptive methodology with a quantitative approach was implemented. It began with an exhaustive review of the literature to identify possible factors that could influence labor performance. With this information, an observation form was designed and applied to 45 workers at six different construction sites within the study area. The data collected were analyzed using statistical software to establish a mathematical model to predict the performance of the workers based on the factors identified. Subsequently, these values were compared with the actual and theoretical performance obtained. Results. One of the most outstanding findings was the notable difference between the actual performance of the workers and the theoretical performance, indicating that performance does not follow a linear trend over time and varies according to various factors such as climatic conditions, equipment used, supervision and individual worker characteristics. Conclusion. The mathematical model developed in this research proved to be effective in predicting worker performance based on the factors analyzed.

Introduction

In today's competitive landscape of the construction industry, where companies strive to differentiate themselves, the ability to assess and improve productivity emerges as a crucial factor in achieving a prominent position in the market (Azeem et al., 2020). One way to improve this productivity is through improving the understanding of worker performance, since it is the workers who, through their capabilities, can execute activities effectively to meet delivery times in a timely manner (Shehata and Gohary, 2019).

Labor Performance (LPO) can be conceptualized as the amount of work that a worker can perform in a given period of time and represents a key indicator of labor productivity that can be an important factor in the success or failure of any company or project. Generally, the control or identification of LPO during a construction activity is carried out through national, international, local or regulatory standards that allow knowing the amount of work (m2) performed that can be expected from a worker for each workday, whether measured in days, hours or minutes (Assaad et al., 2022).

However, the RMO is not a constant quantity that can be used in all construction contexts, since the performance that can be expected from a worker will depend on many factors, both external and internal, that will cause variations (Ángeles et al., 2022). Among the factors that can influence the RMO are: administrative, contractual, personal, technical, procedural and even cultural factors that can vary from region to region, which will cause a diversification of the performance that can be obtained from a worker, depending on the socio-cultural context in which the work is located (Van et al., 2021).

The above factors lead managers to plan their work with greater uncertainty, as there is no guarantee that workers will be able to meet the required workload within the planned time frame. Furthermore, if a construction manager meticulously organizes his work based on a predetermined performance budget and workers subsequently fail to meet the expected standards, delivery deadlines may be missed. This can lead to various complications, including: increased expenses, legal complications, and client dissatisfaction, among other issues (Wang et al., 2023).

In the local framework, specifically in Cuenca-Ecuador, where this research is carried out, construction managers are not exempt from the aforementioned reality, since in this city, construction managers must also work with uncertainty when making their plans, because, despite having RMO data from organizations such as the construction chamber and professional colleges located in Cuenca, the multiculturalism of the workers, different working styles and the lack of standardization in the execution of works in this city significantly hinder this work (Encalada and Calle, 2021; Fajardo and Quizhpe, 2021).

Conversely, there are construction tasks that, while not typically considered critical, have the ability to cause significant delays if not planned properly. These tasks include ceiling installation, an activity that is often underestimated in terms of its influence on the overall duration of a project. While it may seem less important compared to other construction phases, the effective implementation of ceiling installation is crucial to maintaining schedules and managing costs. Therefore, it is important to approach this effort with a meticulous strategy and a comprehensive understanding of the variables that impact the efficiency of the workforce dedicated to this objective (Arias et al., 2022).

Given the aforementioned problem, the following research question is raised: How can the labor performance in ceiling installation projects be projected effectively? In order to address this question, the purpose of this research is to apply a mathematical model to formulate a projection of the labor performance in the ceiling installation activity in Cuenca, through the characterization of one of its most important parishes, that is, the

Parish of San Sebastián. The ultimate goal of this research is to reduce the uncertainty faced by construction project managers in this area.

Projecting RMO on construction projects during the ceiling installation phase will not only significantly reduce the uncertainty faced by construction managers, but will also provide valuable insights into the factors, both internal and external, that exert a significant influence on worker performance. This, in turn, will facilitate more effective project planning, increasing efficiency and satisfaction for both the construction industry and its clients.

The primary audience of this research is construction companies, project managers, and construction workers. They will be able to use the results and forecasts obtained from the mathematical model to improve the planning and implementation of ceiling installation projects. In addition, the community at large will experience benefits such as increased efficiency in the completion of construction projects and the possibility of reducing expenses. These benefits will contribute to the long-term growth and progress of San Sebastian Parish and the City of Cuenca in general.

In this research, the dependent variable analyzed is the RMO in the ceiling installation activity. While the independent variables studied comprise a series of factors, both internal and external, related to these tasks that influence performance. To achieve a more solid understanding of these variables, a detailed framework is provided below:

Labor Performance Index (LPI) and factors affecting it

Workforce performance in the construction industry is a crucial factor that directly impacts the successful completion of projects. The ability to efficiently predict and manage this performance is considered crucial by both construction companies and project managers. However, understanding the various factors that influence worker performance in this field is a complex task, as it encompasses a wide spectrum of elements, ranging from working and administrative conditions to individual factors. This section will examine different viewpoints and methodologies regarding RMO and analyze the impact of these factors on labor productivity and effectiveness in the construction industry.

In the first instance, RMO in the context of the construction industry is defined in a practical and functional way as the amount of work performed in square meters (m2) per unit of time, generally expressed in hours, which is represented as m2/hour (Assaad et al., 2022). According to data from the Cuenca Construction Chamber, most construction activities already have standards established by various organizations specialized in RMO measurement. In other words, each activity in the construction sector has a minimum rate of square meters per hour that is considered as a standard or satisfactory performance (Espinoza et al., 2023).

To ensure that a construction industry employee meets minimum or satisfactory performance standards, it is crucial to create a favorable work environment that facilitates the efficient completion of their tasks. This context encompasses factors such as legislation and regulations, cultural norms, resources, work dynamics, working conditions, as well as internal and external environmental elements, among others. They also highlight the importance of quickly and adequately identifying factors that could influence performance during the contracting phase and project execution. Failure to understand these elements can negatively impact overall performance and lead to delays (Lakhiar et al., 2021).

In terms of identifying factors influencing OMR, multiple perspectives have been considered. Factors such as ineffective workplace communication, limited job autonomy, suboptimal work environment design, lack of proactivity, and inability to propose innovative ideas and approaches to task execution can significantly diminish workers' performance (Diamantidis and Chatzoglou, 2019). From another point of view, performance can be considered to be mainly affected by factors inherent to workers, such as limited cognitive abilities, insufficient work experience, inadequate knowledge in construction work, and lack of discipline (Manoharan et al., 2022).

However, the substantial impact of managerial factors on workers' RMO can be approached from a different point of view than the authors mentioned above. Factors such as site management and coordination, leadership, financial management, planning, commitment, and coordination between management and contractors can either enhance or hinder employee performance (Dixit, 2019). Ineffective management of a construction project can significantly affect performance. This includes issues such as the employment of unskilled workers, inadequate workforce training and development, logistical problems, errors, omissions, and rework, as well as congestion and overcrowding in the work area, along with insufficient coordination (Assaad et al., 2022).

Previous contributions have presented various perspectives on the factors that influence job performance in the construction industry. However, in this research we will adopt the approach suggested by Luis Fernando Botero. Botero's study presents a holistic approach that takes into account various factors such as economic, labor, weather conditions, activities, equipment, supervision and specific aspects of workers. This approach encompasses and expands the previously mentioned points of view, offering a more comprehensive perspective to evaluate workforce performance (WFP) from multiple dimensions (Botero, 2002).

The following are the factors identified by Botero that impact job performance in the construction sector. These factors encompass a multitude of dimensions: The “Climate” factor encompasses the assessment of environmental conditions at the workplace, including aspects such as temperature, rainfall, and soil conditions. Climatic conditions can exert a substantial influence on the efficiency of workers. The “Activity” factor refers to the actions performed by workers in construction and encompasses elements such as the complexity of tasks, the level of risk involved, the consistency of activities, the level of order and cleanliness during execution, the typicality of activities, and the organization of work spaces.

In contrast, the “Equipment” aspect encompasses crucial components such as accessibility to appropriate tools for each task, the presence of safety equipment, the continuous supply of materials and other resources essential for the execution of construction work. The “Supervision” factor refers to the procedures involved in supervising workers and their tasks, encompassing elements such as guidance, instruction, monitoring, training and ensuring the quality of work. The “Worker” factor refers to the individual circumstances of each worker, taking into account factors such as the degree of accumulated fatigue, the ability to perform tasks, prior knowledge and training received. These specific components also impact the efficiency of the construction workforce.

In summary, it can be seen from this section that job performance in the construction industry is a complex phenomenon encompassing a wide range of influences including working conditions, individual factors, and managerial and economic aspects. Various viewpoints have emphasized the importance of understanding and controlling these factors in order to achieve the most favorable worker performance. Implementing the comprehensive approach that considers different viewpoints provides a holistic view that takes into account all these factors together, which is crucial for improving productivity and efficiency in the construction industry. An in-depth examination of these factors will enable construction companies and project managers to make well-informed decisions and devise efficient strategies to improve job performance in this particular context.

Linear regression as a performance projection model

Linear Regression (LR) is a powerful mathematical model widely used in statistics to project, predict and understand the behavior of a phenomenon based on relevant variables. In the context of the construction industry, LR plays a significant role, allowing the projection of key variables, such as ROI. In this section, we will explore the fundamentals of LR, its various variants, formulas and research support, highlighting its importance in predicting and managing performance in this sector.

RL can be defined as a statistical technique used to establish a mathematical model that represents the connection between a dependent variable and one or more independent variables. It is used to predict the value of the dependent variable considering the values of autonomous variables. In simple RL there is a single independent variable, while in multiple RL there are two or more independent variables. For the purposes of this research, multiple linear regression will be used (Maulud and Mohsin, 2020). The expression of this variable is presented below in formula 1.

$$y = b_0 + b_1 * X1 + b_2 * X2 + \cdots + b_N * Xn \quad (1)$$

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

The RL has multiple uses, among which, the projection of yields stands out, an example of this is the research entitled: "Analysis of Performance and/or Productivity of the Labor in the Construction of Buildings in the City of Bucaramanga and its Metropolitan Area: Structures Stage" in which, the multiple RL model was used to establish the equation models that mathematically represent the behavior of the activities under study, with respect to the affecting factors and their incidence on the performance and/or productivity of the labor force in buildings in the Metropolitan Area of Bucaramanga (Molina and Páez, 2013).

Likewise, the study entitled: "Completion of labor performance in 1 / 4' rigid pavements in the city of Huancavelica, applying the multiple regression model with dummy variables" in Peru, specifically in the city of Huancavelica, who used RL to predict the performance that can be obtained from workers in the placement of rigid pavements or at the local level (Cayetano and Zuñiga, 2015). The research entitled: "Labor performance in hand excavations using linear regression. Case study: city of Cuenca" who used RL to predict what performance can be expected from workers in the hand excavation activity in the city of Cuenca (Tola et al., 2023).

As evidenced in the contributions of this section, RL is presented as a coherent and adequate statistical model for the central purpose of this research: projecting labor performance. Specifically, multiple RL has emerged as the most appropriate option, given its capacity to incorporate multiple independent variables and its applicability in predicting worker performance. This model will be established as a solid basis for anticipating performance in the installation of false ceilings in the city of Cuenca, taking into account the factors that influence this activity.

Methodology

Design

The research design used in this study is aligned with the relational-descriptive type. Its objective is to examine the impact of various external and internal factors on the performance of workers engaged in ceiling installation within the San Sebastian parish located in the City of Cuenca, Ecuador. Similarly, a quantitative approach is used, as the data and analysis used in the research are performed statistically through numerical analysis software. For this research, we will focus on the job performance of employees as the dependent variable.

The initial step of the mentioned methodology involves presenting the criteria used for the data collection instrument that was used to collect the information shown in table 1. The table begins with the variables described in Botero's literature, mentioned above in the theoretical section of the introduction that include climatic conditions, factors associated with the activity itself, the type and quality of the workers' equipment, the frequency and nature of supervision provided by the organization and the specific conditions of each individual worker. Each variable is subdivided into different indicators that have a specific numbering that goes from the most unfavorable condition; corresponds to 1, to the most favorable condition; corresponds to 5.

Table 1

Operationalization of variables

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

Conciencia Digital
ISSN: 2600-5859
Vol. 7 No. 1.3, pp.91–112, March 2024
www.concienciadigital.org

	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
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

Table 1

Operationalization of variables (continued)

Variable	Indicators	1	2	3	4	5
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: Authors

The study universe of this research covers ongoing constructions within the parish of San Sebastián. The population selection focuses on one- and two-story buildings that are in the phase of installing false ceilings, with the relevant permits issued by the Decentralized Autonomous Government (GAD) of the municipality of Cuenca. The study sample was determined following a rigorous criterion: constructions that were currently in the stage of installing false ceilings during the data collection period were chosen, with administrators willing to collaborate by providing the permits and access necessary for the study, and works that had not started installing false ceilings before the start of the research.

Following an exhaustive selection process, a final sample of six buildings that met the established inclusion criteria was formed. The data collection process was carried out with the participation of all workers involved in the installation of the ceiling, resulting in a total of 45 workers observed.

The next phase was the analysis of the results, which consisted of a normality test, relationship between categorical sets, linear regression, and a comparison between theoretical, actual, and calculated performances. First, the Shapiro-Wilk test is used to determine whether a sample of data follows a normal distribution. Its p-value, usually set at 0.05, indicates whether there is sufficient evidence to reject the null hypothesis that the data originate from a normally distributed population. If the p-value is greater than this threshold, there is no strong evidence to reject the null hypothesis, suggesting that the data may be normally distributed. However, if the p-value is less than 0.05, the null hypothesis is rejected, indicating that the data do not conform to a normal distribution.

The analysis of variance was carried out after assessing the normality of the data and the Kruskal-Wallis method was used, which uses the chi-square (χ^2) calculation to determine relationships between sets of categorical data, regardless of the assumption of normality. The degrees of freedom (df) in this context represent the independent variables that can change without affecting the restrictions established by the analysis. In addition, a predefined significance level (p) was considered, commonly set at 0.05 or 0.01, but adjustable according to the degree of precision required to assess the statistical significance of the results obtained in the study. This level of significance allows determining whether the differences between groups are large enough not to be attributed simply to chance.

Subsequently, a linear regression analysis was carried out, starting with the evaluation of the adequacy of the model. Metrics such as the linear correlation coefficient (R) were used to measure the relationship between the variables and the coefficient of determination (R^2) to quantify how much variability is explained by the model. In addition, the Akaike (AIC) and Bayesian (BIC) information criteria were used to evaluate the quality of the model, seeking to minimize its values. The root mean square error (RMSE) was used to assess the accuracy of the model in predicting real results, thus offering a comprehensive evaluation of its predictive capacity.

The model coefficients were then obtained using the performance metrics and independent variables listed in Table 1. These coefficients reflect different aspects: the estimated value represents the slope calculated between the variables, the SE coefficient measures the precision of that estimate, and the t coefficient evaluates significant deviations. Finally, the p coefficient indicates the probability of observing that coefficient if there is no real relationship between the variables. These metrics help to understand the reliability of the estimates and determine which relationships between the variables are statistically significant.

Results

Normality analyses, performed using the Shapiro-Wilk test, revealed significant findings, with p values below the 0.05 threshold. These results strongly confirm that the data do not exhibit a normal distribution pattern. This discrepancy with the expected distribution is essential to determine the most appropriate statistical analysis strategies and ensure accuracy in the interpretation of subsequent results, since by not following a normal distribution, strategies that are not dispensable from normality must be used, such as the Kruskal-Wallis analysis, whose results are shown below in Table 2:

Concienca Digital
ISSN: 2600-5859
Vol. 7 No. 1.3, pp.91–112, March 2024
www.concienciadigital.org

Table 2

Kruskal-Wallis analysis

	χ^2	gl	p
Training	38.3	20	0.008
Time	31.8	20	0.045
Temperature	37.5	20	0.010
Floor	33.9	20	0.027
Deck	26.8	20	0.140
Difficulty	30.7	20	0.060
Danger	23.1	20	0.284
Interruptions	27.2	20	0.129
Order and cleanliness	12.8	20	0.887
Previous activities	28.8	20	0.092
Typicality	28.2	20	0.106
Tajo (Workspace)	28.1	20	0.107
Tool	28.2	20	0.104
Equipment	27.6	20	0.118
Maintenance	37.2	20	0.011
Supply	29.5	20	0.079
Protective element	40.2	20	0.005
Address (acceptance criteria)	36.6	20	0.013
Instruction	37.2	20	0.011
Follow-up	37.3	20	0.011
Supervisor (Teacher)	22.5	20	0.312
Quality Assurance	37.5	20	0.010
Personal situation	38.2	20	0.008
Work pace	29.7	20	0.075
Health	35.9	20	0.016
Ability	38.4	20	0.008

The results presented in Table 2 reveal that certain factors, such as training, temperature, floor conditions, maintenance, use of protective equipment, management (assessed according to specific criteria), level of instruction, work monitoring, quality assurance, personal situation, health and skills, exhibit statistically significant differences ($p \leq 0.05$). This indicates that these factors individually have the capacity to significantly influence the performance of workers. In contrast, the remaining factors do not reach the same level of statistical significance (p≥0.05). Therefore, it follows that these factors do not exert a significant influence on the final performance of workers in the activity evaluated.

The model fit calculation is then carried out. As can be seen in Table 3, these data reveal a highly robust and accurate statistical model. The linear correlation coefficient (R) of 0.963 suggests a strong relationship between the model variables, while the coefficient of determination (R^2) of 0.927 indicates that approximately 92.7% of the variability in the dependent variable can be explained by the independent variables, indicating a remarkably high predictive power. The negative values of AIC (-107) and BIC (-68.7) indicate a favorable model fit, with lower values suggesting a better fit. Finally, the low RMSE (Root Mean Square Error) value of 0.0464 indicates a minimal difference between the model predictions and the actual values, evidencing a high accuracy in the model predictions.

Table 3

Model fit measures

Model	R	R^2	AIC	BIC	RMSE
1	0.963	0.927	-107	-68.7	0.0464

With this adjustment, we proceed with the model coefficients shown in Table 4. The value of -0.98162 indicates the expected yield when all predictor variables are zero. However, since the p-value is greater than 0.05, it is not statistically significant. Regarding the time factor, the coefficient of 0.04212 suggests that an increase in time is associated with an increase in yield, but this effect is not statistically significant (p > 0.05). For the temperature factor, a negative coefficient of -0.55393 is observed, indicating that as temperature increases, yield tends to decrease, but again, this effect is not significant. As for the other factors such as: Floor, Cover, Difficulty, Danger, Cut (Work space), Interruptions, Order and cleanliness, Previous activities, Tool, Equipment, Maintenance, Supply, Protective element, Direction (acceptance criteria), Monitoring: For each of these variables, their coefficients and p-values indicate their effect on performance. However, none of these effects is statistically significant since the p-values are greater than 0.05.

Table 4

Model Coefficients - Performance

Predictor	Estimator	EE	t	p
Constant	-0.98162	2.8819	-0.3406	0.736
Time	0.04212	0.0323	1.3041	0.204

Model Coefficients - Performance

Predictor	Estimator	EE	t	p
Temperature	-0.55393	0.3980	-1.3917	0.176
Floor	-0.00333	0.0568	-0.0587	0.954
Deck	-0.73809	0.4932	-1.4965	0.147
Difficulty	-0.17167	0.0951	-1.8057	0.083
Danger	-0.02500	0.0762	-0.3280	0.746
Tajo (Workspace)	-0.52708	0.3089	-1.7066	0.100
Ability	0.12500	0.1164	1.0735	0.293
Interruptions	0.06336	0.1029	0.6157	0.544
Order and cleanliness	0.41393	0.3925	1.0546	0.302
Previous activities	-0.30360	0.2116	-1.4347	0.164
Typicality	1.27388	0.8520	1.4951	0.147
Tool	-0.19414	0.3479	-0.5580	0.582
Equipment	0.33536	0.3039	1.1036	0.280
Maintenance	0.27324	0.3003	0.9098	0.372
Supply	0.24107	0.2157	1.1174	0.274
Protective element	0.68042	0.3832	1.7756	0.088
Address (acceptance criteria)	1.04507	0.7726	1.3527	0.188
Follow-up	-0.58771	0.4079	-1.4408	0.162

Using the data from the estimators, we proceed to calculate the formula for the mathematical model shown below:

Y= - 0.98162 + 0.04212*time - 0.55393*temperature - 0.00333*floor - 0.73809*cover - 0.17167*difficulty - 0.02500*danger - 0.52708*cut + 0.12500*skill + 0.06336*interruptions + 0.41393*cleanliness_order - 0.30360*preceding_activities + 1.27388*typicality - 0.19414*tool + 0.33536*equipment + 0.27324*maintenance + 0.24107*supply + 0.68042*protection + 1.04507*direction - 0.58771*tracking

To demonstrate the efficiency of the performance calculated by the formula, a comparison is made between the actual performance of the workers, which was determined from the observations made at the workplace, the theoretical performance, which is the average performance provided by the Cuenca municipal GAD, which corresponds to 3.33 m2/hour, and the performance calculated by the mathematical model applied in this research.

Figure 1

Comparison between actual, theoretical and calculated performance

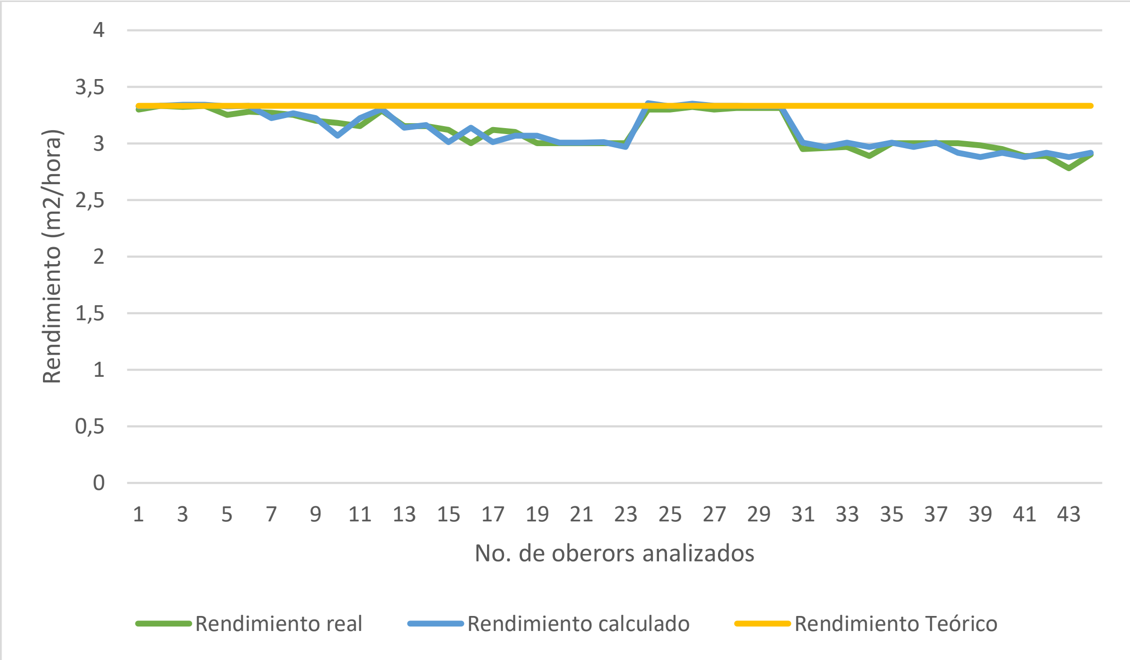
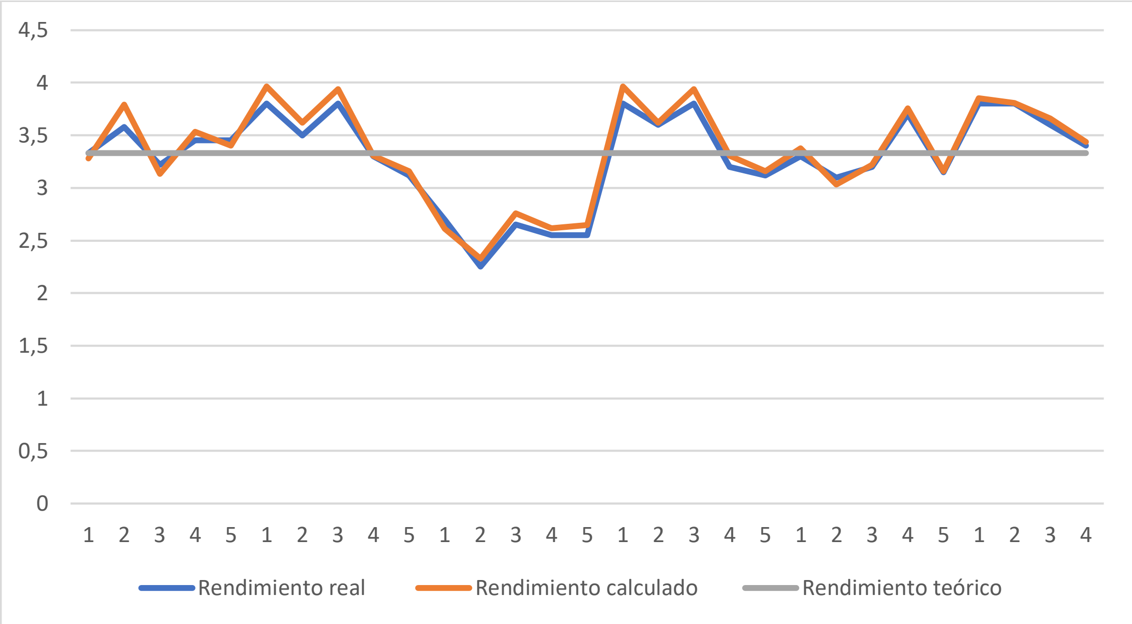


Figure 1 illustrates how the actual performance of workers does not remain constantly in relation to the theoretical performance of 3.33 m²/hour established by the Decentralized Autonomous Government (GAD) of Cuenca, but rather fluctuates between this theoretical value and a minimum of 2.89 m²/hour. However, it can be observed that the performance calculated using the mathematical model based on linear regression fits more accurately to this variability in performance.

In order to test the effectiveness of the formula outside the data collected from the sample for the development of the model, a second application was carried out in 7 different construction sites within the parish of San Sebastián. A worker was randomly assigned to each of the constructions and was monitored with the observation sheet for a work week, that is, 5 days. Then, the results of the actual performance of the workers were compared with the performance calculated with the formula and the theoretical performance shown in Figure 2.

Figure 2

Comparison between actual, theoretical and calculated performance



As can be seen in Figure 2, the actual performance of the workers varied from the theoretical performance; in some cases, the performance greatly exceeded expectations, while in others it was considerably reduced. Furthermore, it is evident that the calculated performance was able to accurately predict these fluctuations. The results table by worker is shown in Table 5.

Table 5

Workers' performance in new constructions

Construction site	Day	Actual performance	Calculated performance	Theoretical performance
Work 1	1	3.3	3.27	3.33
	2	3.68	3.79	3.33
	3	3.2	3.13	3.33
	4	3.5	3.53	3.33
	5	3.4	3.40	3.33
Work 2	1	3.8	3.96	3.33
	2	3.6	3.61	3.33
	3	3.8	3.94	3.33
	4	3.3	3.30	3.33
	5	3.15	3.15	3.33

Concienca Digital
ISSN: 2600-5859
Vol. 7 No. 1.3, pp.91–112, March 2024
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Table 5

Performance of workers in new constructions (continued)

Construction site	Day	Actual performance	Calculated performance	Theoretical performance
Work 3	1	2.7	2.61	3.33
	2	2.25	2.32	3.33
	3	2.7	2.75	3.33
	4	2.6	2.61	3.33
	5	2.6	2.64	3.33
Work 4	1	3.9	3.96	3.33
	2	3.6	3.61	3.33
	3	3.9	3.94	3.33
	4	3.3	3.30	3.33
	5	3.15	3.15	3.33
Work 5	1	3.3	3.37	3.33
	2	3.1	3.03	3.33
	3	3.2	3.21	3.33
	4	3.7	3.75	3.33
	5	3.15	3.15	3.33
Work 6	1	3.8	3.85	3.33
	2	3.8	3.80	3.33
	3	3.6	3.65	3.33
	4	3.4	3.43	3.33
	5	3.1	3.04	3.33
Work 7	1	2.5	2.43	3.33
	2	3.1	3.12	3.33
	3	3.35	3.38	3.33
	4	2.5	2.53	3.33
	5	1.8	1.79	3.33

Conclusions

- Statistical analysis reveals that only a few variables, including: training, temperature, soil conditions, maintenance, use of protective elements, management, level of instruction, work monitoring, quality assurance, personal situation, health and skills, significantly influence the performance of workers during the ceiling installation activity in the San Sebastián parish of the city of Cuenca.
- Although not all variables show statistically significant differences ($p \leq 0.05$), the adjustment measures indicate that by applying linear regression it is possible to develop a predictive model with an effectiveness of 92.7%.

- When comparing the actual performance of the workers with the theoretical performance provided by the Cuenca GAD, a significant difference is observed. This performance does not follow a linear trend over time and varies according to climatic conditions, the specific activity, the equipment used, supervision and the individual characteristics of the worker.
- The mathematical model developed in this research proved to be effective in predicting the performance of workers based on the factors studied. Therefore, it can be used as a predictive tool for the installation of false ceilings in the context of San Sebastián and, more broadly, for the city of Cuenca due to the similarity of its environment.

Conflict of interest

Authors must declare whether or not there is a conflict of interest in relation to the submitted article.

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.

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ISSN: 2600-5859
Vol. 7 No. 1.3, pp.91–112, March 2024

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