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A mathematical model for estimating of the frequency of general medicine service use of the level I health care entity

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ABSTRACT
The planning and programming of resources to serve health sector services are projected from health care needs to offering the beneficiary population or users of such services. The purpose is to maintain a balance between economic and financial sustainabilities with a high social contribution to meet the health needs of a population, becoming necessary to establish the variables which determine the use of these. And this must be done by developing mathematical modeling that allows such projecting the needs and solves resource restriction problems.
This article presents the application of Generalized Linear Models (GLM) [1]. The objective is intended to estimate the frequency of general medicine uses of the level I health care entity. According to various user variables such as a gender, education level, region to which it belongs, status, linkage, and perception of services. The SPSS (Statistical Package for the Social Sciences) statistical computing program was used to obtain the general medicine service results.

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I. INTRODUCTION

The different entities in the health sector must ensure the coverage and assistance of services as a health subsystem. To accomplish the above, it has resources for the provision of the services. These must be optimized in a such way that satisfies all beneficiaries of the system within the framework of the insurance processes, as well as the activities, procedures, and assistance interventions in the promotion and prevention phases, diagnosis, procedures, and rehabilitation of health condition.

Based on the requirement of a basic level of care and the benefit of health promotion and disease prevention programs as parts of the family health-oriented care model, a model for estimating the frequency of the health subsystem's the general medicine service use was determined. The model has developed initially with the characterization phases of the variables within the health system, related to the frequency of use of this system. In the second phase, the variables included in the health system were determined, which define or explain the frequency of use of this system. In the third phase, the appropriate multivariate data analysis model was established to forecast the frequency of use in health entities. In the last step, the statistical validation of the established model was carried out. The model was developed in the characterization phases of the variables within the health system, related to the frequency of use of this system. In the second phase, the variables included in the health system were determined, which define or explain the frequency of use of this system. In the third phase, the appropriate multivariate data analysis model was established to forecast the frequency of use in health entities. In the last step, the statistical validation of the established model was carried out.

The article focuses on developing a generalized linear model (GLM), which is a flexible generalization of ordinary linear regression that allows response variables that have error distribution models other than a normal distribution. These have three necessary components: 1) A random component that identifies the response variable and its probability distribution, 2) A systematic component that specifies the explanatory variables (independent or predictors) used in the linear predictor function, and 3) Binding function, being a function of the expected value of Y, E(Y), as a linear combination of predictor variables. This model was found and the respective validation using statistical computing software such as SPSS.

The frequency of use is defined as when a patient attends consultation during a specified period [2] and reflects a part of the well-being of users of the health subsystem. The problem is that the system does not have a mathematical model for determining demand based on the factors and the incident variables in the frequency of use of the general medicine system service. That allows the identification of the required resources and proposes health prevention and promotion programs, thereby defining the budget resources as are necessary for the provision of health services [3].

On the other hand, the frequency of use cannot be observed like a simple number but requires the conjugation of factors and variables that allow describing the reason for the user's decision to make use of the health service. The frequency of use does not define the effectiveness of treatment or the solution to the health problem being consulted. It is a number that allowing to project the entry of patients into the subsystem. It defines the future potential demand of the subsystem by establishing the distance between the indicators defined by the state and the actual ones of the subsystem.

In addition, there is a good number of work carried out in the area of health, which support this work, as mentioned in the literature referred to in [4] to [37].

II. MATERIAL AND METHODS

2.1 Methodology

Based on the systematic collection and review of information from the database of care records to users of the country's health system, and especially of the capital city, the interacting variables in the system are identified, characterized, and defined for further analysis and use in the development of the model that is designed. Following, it develops the evaluation system that verifies the optimal solution offered by the developed model and the real needs of public health companies in the patient care, using as a tool for the calculation of the results of the application SPSS.

2.2 Model design

Independent variables that influence or intervene in the frequency of use of the general medicine service are identified through exploratory analysis of the data as well as a preliminary analysis of the variables that can integrate the mathematical model. This Exploratory Data Analysis (EDA) is an approach to data analysis that employs a variety of techniques for the purpose of: extending knowledge of a dataset; reveal the underlying structure; obtain important variables; discover outliers and anomalies; experience underlying assumptions; develop parsimonious models; and set the optimal factor settings.

Another tool used is the analysis of main components, is a structural or interdependence technique, where all variables are equally important and independent (Garza García, 2013); it is a dimension reduction tool used in multivariate analysis problems which can contain a substantial number of correlated variables. And it aims to reduce a large set of variables to a small set that still contains most of the information in the large set. Applied this technique, the analysis of main components on the data reason for study, it was obtained that the variables that contribute above 10% and explain the frequency of use of the health system at level I, are the Improvement in health, Quality in care, Type of Linkage, Sex and Waiting Time. The other variables are reasonably explanatory except for the Region variable, which contributes less than 5%; these results will be consistent when obtaining the GLM model parameters adjusted to the system data under study.

2.3 Formulating the problem

The problem is to determine the frequency of use of the general medicine service, which allows decisions to be made on the resources required and propose preventive health and health promotion programs, thereby determining the necessary budgetary resources to provide health services.

The proposed mathematical model contains the health determinants that describe the frequency of use, through the definition of independent variables as the doctor's visits frequency. These determinants are gender, age, education level, the region to which a patient belongs, or is registered to access the services, the employee status, the perception of service, and these are described below.

- Consultations: represents the frequency of general medicine events, i.e., the number of times a user is attended by a general practitioner in the period from the last eight months of 2018 or better the number of times a user visits general medicine.
- Gender: defined as male (0) and female (1).
- Age: a variable that identifies each patient according to their biological age. The range is 18 to 92 years.
- Education level: includes the categories of academic training: basic academic, technical, higher, specialization, and none. For calculation purposes, it is classified as Basic (1), specialization (2), None (3), Superior (4), and Technical (5).
- Region: This variable differentiates the region from which general medicine patients come from being served by the Bogota Section. Under the planning of health services network to ensure the provision of services according to the geographical distribution of demand. The geographical divisions are established by region to provide a regulatory response such as accessibility, timely care assurance, economics for user accessibility, and coverage. The regionals are distributed in eight (8) who administer and, manage resources, and establish the services needs to be offered according to the epidemiological profile of the departments that make it up, as well: Bogotá, Cundinamarca, Boyacá, Amazonas, San Andrés, and Guainía; Huila, Tolima, Putumayo,

and Caquetá; Risaralda, Caldas, Quindío; Valle del Cauca, Cauca, Nariño and Valle; Santander, Norte de Santander, and Arauca; Antioquia Urabá Córdoba y Chocó; Meta, Casanare, Guaviare, and Vichada; And Atlantic, Bolivar, Cesar, Magdalena, Guajira, and Sucre respectively.

- Employee Status: Users are classified into reference groups within the health information system as well: Active (1), Retirement Assignment (2), Beneficiary (3), Deceased (4), Vacations (5), Time Pensioner (6), Deceased Pensioner (7), High Retiree (8), Retiree (9), Deceased Retiree (10) and Disability Pensioner (11).
- Linkage: consists of four large groups that within it is subdivided into non-uniformed users (employees and beneficiaries) and uniformed. The uniformed are personnel from patrolman to general and who are classified as executive level, officers, and non-commissioned officers: Non-uniformed (1), Executive Uniformed (2), Officer (3), and Non-commissioned officers (4).

The following variables within the model evaluate how users of the subsystem perceive the service provided, which is obtained from the annual satisfaction survey that applies to patients receiving the general medicine service:

- Waiting time: Patient perception of care time, with evaluation from zero (0) to five (5) being zero the minimum waiting, and five the maximum time as observed by the patient.
- Improvement of a health condition: Patient perception of treatment received, with evaluation from zero (0) to five (5) being zero non-improvement and five as the maximum by improvement or solution of a disease.
- Quality of health care: Patient evaluation by the service delivery, taking as zero (0) as the minimum and five (5) maximum quality value, according to the patient's criteria.
- Overall Satisfaction: identifies the degree of patient satisfaction by the service provided by evaluating as one (1) for satisfied and zero (0) for non-satisfied.

III. RESULTS

3.1 Survey Design Mathematical model

Based on the results obtained in the previous section, a mathematical model is built, considering the following steps.

3.2 Dependent variable definition (Y) and independent variables

The cause-effect relationship, or the variable(s) that explain the dependent variable's behavior, is searched, and this is proposed through the mathematical model of multiple regression. The different methods were used, such as complete, forward, backward, stepwise, the last three interact by entering or removing independent variables after their significance assessment or explanation contribution within a model regarding an entire model.

The proposed multi-regression model (equation 1) is presented as follows. The proposed multi-regression model is shown as follows [1]:

$$Y = \beta\_0 + \beta\_1\, X\_1 + \beta\_2\, X\_2 + \cdots + \beta\_n\, X\_n \qquad (1)$$

Where:

Y: Dependent variable, number of consultations per health subsystem user

Xi: Independent, explanatory, or influence variables i. Gender, Age, Education Level, Region, Employee Status, Linkage, Waiting time to access the service, Perception of improvement of a health condition, Quality of health care, and Overall satisfaction.

β_i: Model coefficient for the variable Xi. Measures the marginal effect on the response of a unit increase, when the rest of the independent variables remain constant. It is the product of historical biostatistical user's information who used the system during the last periods analyzed.

The functional equation of the multiple regression model (equation 2) that was projected, and will represent the attention model is:

$$\begin{aligned} Y = {} & \beta\_0 + \beta\_1\, Gender + \beta\_2\, Age + \beta\_3\ 〚Education〛\_Level + \beta\_4\, Region + \\ & \beta\_5\ 〚Employee〛\_Status + \beta\_6\, Linkage + \beta\_7\ 〚Waiting〛\_Time + \\ & \beta\_8\ 〚Improvement〛\_ + \beta\_9\ 〚Quality〛\_ + \\ & 〚\beta 1〛\_10\ 〚Overall〛\_Satisfaction \end{aligned} \qquad (2)$$

3.3 Model coefficients

The coefficients of the multiple regression equation were then calculated to construct the respective regression function. The following are the values calculated using the SPSS program, for each of the variables: Constant 49,471; Gender,847; Age 1,777; Education_Level 8,896; Region 0.796; Employee_Status 1,911; Linkage 2,932; Waiting_Time -1,062; Improvement_Health_Care 0.069; Quality_Health_Care -0.426 and Overall_Satisfaction -40,073.

Although the value of the adjusted squared R-determination coefficient is above 0.704, this and the other values presented in the above tables alone are not sufficient. Series of tests are performed to ensure that they are significant and can ensure that they sufficiently explain the independent variable's behavior called consultations. Among the different statistical tests applied, the following were used: (a) Collinearity or multicollinearity identification; (b) The correlation between independent variables (rij), which measures the bivariate linear relationship or the association force between two independent variables and is used to measure multicollinearity, where the criterion used is that the absolute value result is greater than and equal to 0.7 to indicate that there are correlation and multicollinearity between the independent variables studied [1]; (c) The T Student hypothesis test for population correlation (A) was used to test whether two variables are linearly related or not. The above tests yielded satisfactory results.

3.4 Selection of variables to include in the model

The F-test compares in the reduced models the partial F; these indicate which is the best. For this case, a complete and two reduced models were made, which were developed, taking into account the backward or phase-out technique (backward) and the forward or progressive introduction (forward) technique; all the R squared are above 0.703. In the reduced processes, It results in the variables Age, Employee_Status, Education_Level , Overall_Satisfaction, Linkage, and Region as explanatory variables of the model, and a coefficient of determination of 0.704 or 70.4% is obtained. In the Backward, Forward, and Stepwise methods, these match five (5) model predictors: Age, Employee_Status , Education_Level , Overall_Satisfaction, and Linkage.

As is well shown, in the results obtained against the reduced models, it is essential to note that it is not appropriate for this research to eliminate the variables of Region, Quality_Health_Care, Gender, Improvement_Health_Care, and Waiting_Time. Because the coefficient of determination indicates the contribution to the explanation of the dependent variable, for biostatistical reasons, the disease in patients can be presented according to gender, the region (epidemiological profile of each geographical location), and the others for particular institutional reasons.

3.5 The contribution identification or total model variation

One statistic that allowed us to identify the contribution of each of the independent variables to the model proposed was the coefficient of determination, which not only informs about the portion that explains but also what does not explain the equation of the model. Within the results of the Anova are the $_{Fc}$ theoretical at a confidence level of 95% with 10, and 2316 degrees of freedom respectively is 1.835, the F calculated > F_c theoretical or the p-value (sig) < alpha is 0.05. Therefore, the hypothesis that all independent variables contribute to the studied model cannot be rejected.

3.6 Validation of the proposed model.

A fundamental stage in the development of a model is practical validation [1]. It was performed to compare the results of the model with observations derived from the system under study. It has been used statistical methods, with an acceptable level of confidence, so that inferences are correct. The way to evaluate the model is based on errors; these forms are:

a) The coefficient of determination indicates that the ten variables proposed in the mathematical model, explain the dependent variable at 70.5% linearly.

b) The corrected or adjusted determination coefficient indicates in percentage terms how much variability of the dependent variable was captured with the proposed regression model, adjusted by the degrees of freedom.

c) The multiple correlation coefficient indicates the association or relationship that independent variables have with the dependent variable. For this research, the result of R-2 is 0.704, and its square root is 0.839, equivalent to 83.9%.

d) The standard error of the estimate indicates that the model obtained is also adjusted to the data, i.e., that so much dispersion presents the historical data versus the proposed regression model.

e) PP Charts, the latter, show some normality of the data; however, towards the central values, there is a slight variation. The other tests resulted in the acceptance of the results.

3.7 Frequency projection of general medicine service use.

Once validated the mathematical model is used for calculation of the frequency of use, the one involving all variables and with which 70.4% of the dependent variable is explained is (equation 3):

$$\begin{aligned} Consultations = {} & 49.417 + .847Gender + 1.777Age + 8.896 〚Education〛\_Level \\ & + 0.796Region + 1.911 〚Employee〛\_Status + 2.932Linkage \\ & - 1.062 〚Waiting〛\_Time + 0.069 〚Improvement〛\_ \\ & - 0.426 〚Quality〛\_ - 40.073 〚Overall〛\_Satisfaction \end{aligned} \quad (3)$$

The mathematical model for calculating the optimal frequency of use according to the SPSS statistical program using five variables and 70.4% of the dependent variable is also explained (equation 4):

$$\begin{aligned} Consultations = {} & 39{,}682 + 1{,}761Age + 8{,}949 〚Education〛\_Level \\ & + 1{,}857 〚Employee〛\_Status + 3{,}176Linkage \\ & - 35{,}518 〚Overall〛\_Satisfaction \end{aligned} \quad (4)$$

3.8 Projection of the Consultations

The value of the forecasts for the consultations variable is satisfied with a confidence level of 95%, with a median of 89 and within the range of 61 to 139 for 90% of the population analyzed. The 10% of the remaining population is above the value of 140, which corresponds to appointments from staff who have been affected exceptionally due to the service provided at the study institution and need various procedures as well as control visits.

3.9 Resulting products

It has obtained the mathematical model that allowed forecasting the frequency of use of the general medicine service. The model is based on ten causal variables' analysis. Such as gender, age, education level, patient region, employee status, linkage, waiting time for service, improvement of a condition status, perception of the service quality, and patient satisfaction, versus the consultations number (as the dependent variable or predicted), with their respective validation.

IV. CONCLUSION

According to the development of this research, a GLM model was built with which the frequency of use in a level I health care entity can be predicted, ensuring the provision of the appropriate service and demand coverage in its care centers.

The GLM model establishes the relevant variables in the prediction of frequency of use, this being a useful tool in financial and operational decision-making when it comes to opening or closing the care facilities of the health care entity taken as a pilot.

Descriptive analyses of the data in conjunction with the use of principal component analysis coincided with the results offered by the computer application, on variables that influence the frequency of use of the level I health care service.

As a result of the research and statistical application presented, it is possible to conclude that there is a relationship between the frequency of use and the ten described variables describing the behavior of first by more than 70%.

The process of validating a model, it is always dependent on the actual system against which the study is to be performed and the permissible error in the model.

The information owner is satisfied with the model's results, and this source is useful for decision-making in the allocation and planning of human and economic resource uses in the presentation of the health service.

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