International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 11, Number 11 (2018), pp. 1699-1712

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Computational model based on Shannon entropy to analyze violence against women: A case study in Peru

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ABSTRACT

Violence against women is a social problem that not only affects women involved, but also their relatives and their environment. In Peru, it is a topic that is becoming increasingly more visible. In this work, a computational model based on the entropy-weight method, which is an approach from Shannon entropy theory, was used. The entropy-weight method was applied to calculate the weights of the criteria; and then, the departments studied were classified according to the results of a weighted sum. The evaluation criteria were physical violence against women (C1), sexual violence (C2), psychological violence (C3), women who suffered violence and sought help (C4), reported cases of family or sexual violence (C5), gender inequality in the labor force (C6), and victims of femicide (C7). This article presents a map of information on the departments with the highest rate of violence against women. The results showed that the two departments with very high violence against women were Madre de Dios and Moquegua; and the two departments with low violence against women were Lambayeque and Amazonas. The method showed interesting results and could be applied to modeling other types of social problems.

Keywords - Violence against women; Shannon entropy; Entropy-weight method.

I. INTRODUCTION

According to the World Health Organization (WHO), violence against women is one of the most serious current problems in terms of health and human rights [1]. In addition, the United Nations defines violence against women as any act of gender-based violence that results in, or may result in, physical, sexual or psychological harm to women, including threats of such acts, coercion or arbitrary deprivation of freedom, whether they occur in public or private life [2], is a phenomenon that occurs in all countries, social classes and spheres of society. It includes not only physical aggression, but also psychic and sexual abuse [3].

In turn, in 2013 an analysis conduct by WHO with the London School of Hygiene and Tropical Medicine and the South Africa Medical Research Council, used existing data from over 80 countries and found that worldwide, 1 in 3, or 35%, of women have experienced physical and/or sexual violence by an intimate partner or non-partner sexual violence [4]. In addition, almost one third (30%) of all women who have been in a relationship have experienced physical and/or sexual violence by their intimate partner. The prevalence estimates of intimate partner violence range from 23.2% in high-income countries and 24.6% in the WHO Western Pacific region to 37% in the WHO Eastern Mediterranean region, and 37.7% in the WHO South-East Asia region [5].

In Peru there is a great diversity of cultures that are the result of their adaptation to specific geographical contexts and are conditioned by different economies and ecologies. These differences have given rise to a variety of cultural systems of shared rules, norms, meanings and expectations, including gender roles, the sexual division of labor, the sexual division of power, social norms of gender, public representation with respect to violence and honor, etc. [6]. In 2016, the Ministry of Women and Vulnerable Populations of Peru, has registered that the most extreme manifestation of gender violence, femicide, claimed the lives of 124 women [7].

Then, in order to analyze violence against women in Peru, a computational model based on the entropy weight method, which is an approach from the Shannon entropy theory, was used. This method was applied to calculate the objective weights of the criteria; as if there was a big difference between the alternatives, the criterion will give decision-makers a great amount of information and the criterion can be considered as an important factor, as evidenced by the study to solve a problem of prioritization of strategies [8], to evaluate an environmental conflict [9], or social topics [10]. Therefore, the specific objective in this study is to determine a ranking of the departments of Peru, on violence against women, applying the entropy-weigh method.

In this work, Section 2 provides the details of the entropy-weight method. In Section 3, the case study is described, followed by the results and discussion in Section 4. The conclusions are provided in Section 5.

II. METHODOLOGY

In this section, the computational model, which is based on the entropy-weight method is described as follows:

2.1 THE SHANNON ENTROPY THEORY

The Shannon entropy theory was initially developed by Claude E. Shannon [11]. The concept of Shannon entropy is applied to measuring the contrast among criteria and this information is used for decision-making [12]. In addition, Shannon developed measure H that satisfied the following properties for all p_i within the estimated joint probability distribution P [13,14]:

1. H is a continuous positive function;
2. If all p_i is equal, pi=1/n , then H should be a monotonic increasing function of n; and,
3. For all, $n \geq 2$, $H(p_1, p_2, \dots, p_n) = h(p_1 + p_2, p_3, \dots, p_n) + (p_1 + p_2)H\left(\frac{p_1}{p_1+p_2}, \frac{p_2}{p_1+p_2}\right)$

He showed that the only function that satisfied these properties is:

$$H_{Shannon} = -\sum_i p_i log\,(p_i) \tag{1}$$

2.2 THE ENTROPY-WEIGHT METHOD

Now, the entropy-weight method, which is based on Shannon entropy, can be developed according to the following definition [15].

Assume that there are m objects for evaluation and n evaluation criteria, which form the decision matrix $Z = \{z_{ij}; i = 1,2, \dots, m;\ j = 1,2, \dots, n\}$. Then, the steps of the entropy-weight method can be expressed as follows:

Step 1: The matrix $Z = \{z_{ij}; i = 1,2, \dots, m;\ j = 1,2, \dots, n\}$ is normalized for each criterion C_j. The normalized values P_{ij} are calculated by Eq. 2.

$$P_{ij} = \frac{z_{ij}}{\sum_{i=1}^{m} z_{ij}} \tag{2}$$

Step 2: The entropy H_j of each criterion C_j is calculated by Eq. 3.

$$H_j = -k \sum_{i=1}^{m} P_{ij} \ln(P_{ij}) \tag{3}$$

where: $k = (\ln(m))^{-1}$

Step 3: The degree of divergence div_j of the intrinsic information in each criterion C_j is calculated by Eq. 4.

$$div_j = 1 - H_j \tag{4}$$

Step 4: The entropy weight w_j of each criterion C_j is calculated by Eq. 5.

$$w_j = \frac{div_j}{\sum_{i=1}^{m} div_j} \tag{5}$$

III. CASE STUDY

The context in which the study was performed and the calculations using the entropy-weight method are described as follows:

3.1 DESCRIPTION OF THE CONTEXT

For this study, the 25 departments of Peru (including a constitutional province called Callao) were considered.

The statistical data used in this work were obtained from organism of Peruvian government: National institute of Statistics and Information (INEI) [16-22] and Ministry of Women and Vulnerable Populations (MIMP) [7]. Then, the criteria established in this study were the following:

3.1.1 CRITERIA REGARDING TO TOTAL FEMALE POPULATION IN EACH DEPARTMENT

The evaluation criteria stablished to this study were determined according to official information from Peru government and by consultation from experts on social topics.

The data of these criteria was obtained regarding to total female population in each department, this information is presented in Table 1.

C1: Percentage of physical violence against women.

It refers to the physical violence exerted once by the husband or partner throughout his life [16].

C2: Percentage of sexual violence against women.

It refers to the sexual violence exerted once by the husband or partner throughout his life [17].

C3: Percentage of psychological or verbal against women.

Refers to psychological or verbal violence exerted once by the husband or partner throughout his life [18].

C4: Percentage of women who suffered violence and sought help.

It covers women of childbearing age who asked for help in some institution [19].

C6: Index of gender inequality in the labor force indicator.

This is an indicator of gender inequality index referring to employment; it covers women over 15 years old, according to the department [20].

3.1.2 CRITERIA REGARDING TO EACH THOUSAND WOMEN IN EACH DEPARTMENT

The data of these criteria was obtained regarding to thousand women in each department, this information is presented in Table 1.

C5: Reported cases of family or sexual violence.

These cases were registered by the MIMP (Ministry of Women and Vulnerable Populations) [21,22].

C7: Case of victims of femicide.

These cases were registered by the MIMP. The data are those registered by the CEM (Women's Emergency Center) in each department, for the Lima department, we add the cases registered in Lima Metropolitan and Lima Province [7,22].

All the criteria were considered direct, since if any increase its value, the indicator of violence against women would also increase. The data obtained from Peru government is presented in Table 1:

Table 1

Departments identified in the Case Study

Cod	**Department**	**C1**[16]	**C2**[17]	**C3**[18]	**C4**[19]	**C5**[21,22]	**C6**[20]	**C7**[7,22]
D1	Amazonas	25.7	7.1	56.5	26.6	4.2	69.7	5E-06
D2	Ancash	28.4	5.9	61.3	25.9	5.6	67.4	0.009
D3	Apurimac	45.8	12.7	75.6	36.9	4.9	78.4	0.013
D4	Arequipa	38.3	10.9	70.1	29.8	4.9	60.7	0.009
D5	Ayacucho	39.7	9.9	62.4	33.1	5.3	70.9	0.015
D6	Cajamarca	28.9	5.8	58.1	20.9	2.9	71.4	0.003
D7	Callao	29.3	4.9	57.6	24.9	2.5	60.9	0.008
D8	Cusco	39.8	14.1	71.4	33.0	9.2	76.2	0.009
D9	Huancavelica	35.5	8.2	70.8	25.6	4.8	78.9	0.008
D10	Huanuco	26.8	7.7	69.4	30.1	4.2	68.6	0.005
D11	Ica	28.7	6.4	62.5	29.1	5.2	61.2	0.003
D12	Junin	40.6	7.8	63.7	24.8	5.7	70.3	0.009
D13	La Libertad	20.9	5.0	54.7	21.5	2.6	61.6	0.015
D14	Lambayeque	23.8	3.9	61.0	22.9	1.0	60.6	2E-06
D15	Lima	31.5	4.6	64.4	25.6	3.0	61.4	0.009
D16	Loreto	23.2	3.2	65.6	21.8	3.5	59.1	0.002
D17	Madre de Dios	38.2	10.5	65.8	35.3	10.1	63.1	0.033
D18	Moquegua	32.9	7.8	66.5	38.3	6.4	65.8	0.035
D19	Pasco	30.5	5.7	68.2	25.4	5.3	67.8	0.007
D20	Piura	32.3	6.2	68.4	34.0	2.7	56.2	0.004
D21	Puno	42.2	13.5	76.0	31.9	3.8	77.0	0.004
D22	San Martin	38.2	10.4	60.6	25.7	6.7	58.5	0.005
D23	Tacna	33.4	7.6	55.3	33.6	4.0	65.9	0.024
D24	Tumbes	31.3	6.7	64.5	28.5	5.0	61.1	0.018
D25	Ucayali	31.0	4.2	65.8	22.2	3.6	66.8	0.008

3.2 CALCULATIONS

The calculations for the case study using the detailed steps of the entropy-weight method were processed as follows:

Step 1: First, the values of each criterion were normalized using Eq. 2. The results are presented in Table 2.

Table 2

Normalized values in the Case Study

Cod	C1	C2	C3	C4	C5	C6	C7
D1	0.031	0.037	0.035	0.038	0.036	0.042	2E-05
D2	0.035	0.031	0.038	0.037	0.048	0.041	0.035
D3	0.056	0.066	0.047	0.052	0.042	0.047	0.052
D4	0.047	0.057	0.043	0.042	0.042	0.037	0.036
D5	0.049	0.052	0.039	0.047	0.045	0.043	0.058
D6	0.035	0.030	0.036	0.029	0.025	0.043	0.010
D7	0.036	0.026	0.036	0.035	0.022	0.037	0.030
D8	0.049	0.074	0.044	0.047	0.078	0.046	0.036
D9	0.043	0.043	0.044	0.036	0.041	0.048	0.032
D10	0.033	0.040	0.043	0.043	0.036	0.041	0.018
D11	0.035	0.034	0.039	0.041	0.044	0.037	0.010
D12	0.050	0.041	0.039	0.035	0.049	0.042	0.035
D13	0.026	0.026	0.034	0.030	0.022	0.037	0.058
D14	0.029	0.021	0.038	0.032	0.008	0.037	0.000
D15	0.039	0.024	0.040	0.036	0.026	0.037	0.034
D16	0.028	0.017	0.041	0.031	0.030	0.036	0.008
D17	0.047	0.055	0.041	0.050	0.086	0.038	0.131
D18	0.040	0.041	0.041	0.054	0.055	0.040	0.138
D19	0.037	0.030	0.042	0.036	0.045	0.041	0.027
D20	0.040	0.033	0.042	0.048	0.023	0.034	0.017
D21	0.052	0.070	0.047	0.045	0.033	0.046	0.017
D22	0.047	0.055	0.037	0.036	0.057	0.035	2E-02
D23	0.041	0.040	0.034	0.047	0.034	0.040	0.094
D24	0.038	0.035	0.040	0.040	0.043	0.037	0.071
D25	0.038	0.022	0.041	0.031	0.031	0.040	0.033

Step 2: The entropy H_j of each criterion C_j is calculated by Eq. 3. The results are presented in Table 3.

Table 3

Entropy values in the Case Study

Cod	C1	C2	C3	C4	C5	C6	C7
D1	0.034	0.038	0.036	0.038	0.037	0.041	7E-05
D2	0.036	0.033	0.039	0.038	0.045	0.040	0.036
D3	0.050	0.056	0.045	0.048	0.042	0.045	0.048
D4	0.045	0.051	0.042	0.041	0.041	0.038	0.037
D5	0.046	0.048	0.039	0.044	0.043	0.042	0.051
D6	0.037	0.033	0.037	0.032	0.028	0.042	0.015
D7	0.037	0.029	0.037	0.037	0.026	0.038	0.033
D8	0.046	0.060	0.043	0.044	0.062	0.044	0.037
D9	0.042	0.042	0.043	0.037	0.040	0.045	0.034
D10	0.035	0.040	0.042	0.042	0.037	0.041	0.023
D11	0.037	0.035	0.039	0.041	0.043	0.038	0.014
D12	0.046	0.041	0.040	0.037	0.046	0.042	0.036
D13	0.029	0.030	0.036	0.033	0.026	0.038	0.051
D14	0.032	0.025	0.038	0.034	0.012	0.038	2E-05
D15	0.039	0.028	0.040	0.037	0.029	0.038	0.035
D16	0.031	0.021	0.040	0.033	0.033	0.037	0.012
D17	0.045	0.049	0.040	0.046	0.066	0.039	0.083
D18	0.040	0.041	0.041	0.049	0.050	0.040	0.085
D19	0.038	0.033	0.041	0.037	0.043	0.041	0.031
D20	0.040	0.035	0.042	0.045	0.027	0.036	0.021
D21	0.048	0.058	0.045	0.043	0.035	0.044	0.021
D22	0.044	0.049	0.038	0.037	0.051	0.037	2E-02
D23	0.041	0.040	0.036	0.045	0.036	0.040	0.069
D24	0.039	0.037	0.040	0.040	0.042	0.038	0.058
D25	0.039	0.026	0.040	0.034	0.033	0.040	0.035

Step 3: The degree of divergence div_j of each criterion C_j is calculated by Eq. 4. The results are presented in Table 4.

Step 4: The entropy-weight w_j of each criterion C_j is calculated by Eq. 5. The results are presented in Table 4.

Table 4

Divergence and Entropy-weight values in the Case Study

Cod	C1	C2	C3	C4	C5	C6	C7
Divergence	0.006	0.022	0.001	0.005	0.027	0.001	0.081
Entropy-weight	0.040	0.156	0.008	0.033	0.187	0.010	0.566

$\sum div = 0.1439$

In this part, the application of the entropy-weight method was finished. Then, the ranking obtained by a pondered sum are descripted and discussed in the next section.

IV. RESULTS AND DISCUSSION

The values of the decision matrix (Table 2) are recalculated taking into account the weights of the criteria (Table 4).

Then, to obtain the ranking, a pondered sum is used [23]. The ordered results are presented in Table 5.

Table 5

Ranking of the studied departments

Cod	Department	C1	C2	C3	C4	C5	C6	C7	Pond Sum
D17	Madre de Dios	0.002	0.007	3E-04	0.001	0.014	3E-04	0.083	0.108
D18	Moquegua	0.001	0.005	3E-04	0.002	0.009	3E-04	0.088	0.105
D23	Tacna	0.001	0.005	2E-04	0.001	0.005	3E-04	0.060	0.074
D24	Tumbes	0.001	0.005	3E-04	0.001	0.007	3E-04	0.045	0.060
D5	Ayacucho	0.002	0.007	3E-04	0.001	0.007	4E-04	0.037	0.054
D3	Apurimac	0.002	0.009	3E-04	0.001	0.007	4E-04	0.033	0.053
D8	Cusco	0.002	0.010	3E-04	0.001	0.012	4E-04	0.023	0.049
D13	La Libertad	0.001	0.003	2E-04	0.001	0.003	3E-04	0.037	0.046
D4	Arequipa	0.002	0.007	3E-04	0.001	0.007	3E-04	0.023	0.040
D12	Junín	0.002	0.005	3E-04	0.001	0.008	4E-04	0.022	0.038
D2	Ancash	0.001	0.004	3E-04	0.001	0.007	3E-04	0.022	0.036
D9	Huancavelica	0.001	0.006	3E-04	0.001	0.006	4E-04	0.020	0.035
D22	San Martin	0.002	0.007	3E-04	0.001	0.009	3E-04	0.013	0.032
D25	Ucayali	0.001	0.003	3E-04	0.001	0.005	3E-04	0.021	0.032
D15	Lima	0.001	0.003	3E-04	0.001	0.004	3E-04	0.021	0.031
D19	Pasco	0.001	0.004	3E-04	0.001	0.007	3E-04	0.017	0.031
D7	Callao	0.001	0.003	3E-04	0.001	0.003	3E-04	0.019	0.029
D21	Puno	0.002	0.009	3E-04	0.001	0.005	4E-04	0.010	0.029

Cod	Department	C1	C2	C3	C4	C5	C6	C7	Pond Sum
D10	Huánuco	0.001	0.005	3E-04	0.001	0.006	3E-04	0.012	0.026
D20	Piura	0.001	0.004	3E-04	0.001	0.004	3E-04	0.011	0.022
D11	Ica	0.001	0.004	3E-04	0.001	0.007	3E-04	0.006	0.021
D6	Cajamarca	0.001	0.004	3E-04	0.001	0.004	4E-04	0.007	0.017
D16	Loreto	0.001	0.002	3E-04	0.001	0.005	3E-04	0.005	0.014
D1	Amazonas	0.001	0.005	2E-04	0.001	0.006	3E-04	1E-05	0.013
D14	Lambayeque	0.001	0.003	3E-04	0.001	0.001	3E-04	4E-06	0.006

From Table 5, the information for the creation of an informative map was obtained. The map indicates the departments of Peru separated into five groups, each group is represented by a different color (green, light green, yellow, orange and red) are shown in Fig. 1.

The departments in green don not imply that violence against women does not exist, but is minimal compared to the other departments.

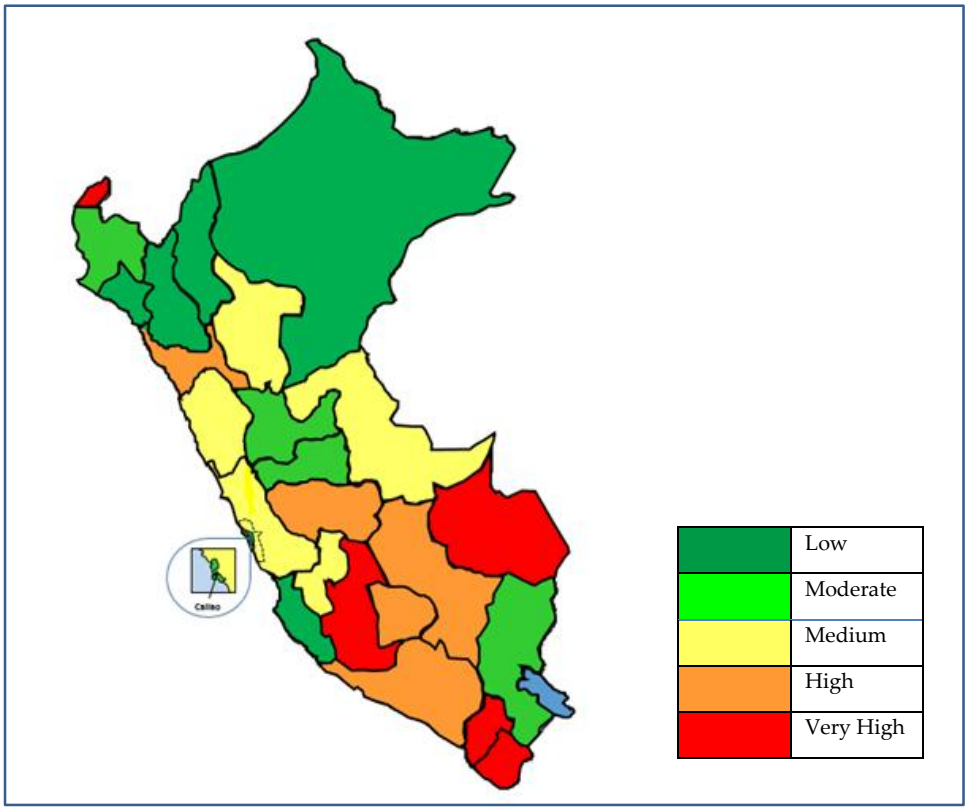

Fig. 1. Map Informative of Violence against women

From Fig. 1, we can see that the departments with very high violence against women were: Madre de Dios, Moquegua, Tacna, Tumbes and Ayacucho. In addition, the departments with low violence against women were: Lambayeque, Amazonas, Loreto, Cajamarca and Ica.

The violence in its different types has been studied previously by other authors and organizations, and then some studies and the methods used area mentioned below.

First, the Colombian State measuring violence against women, mainly through two procedures a) the administration of individual registration of complaints and deaths and b) the realization of empirical data. This responsibility lies with the entities which, by your daily activity, have the commitment and the possibility of doing so; although their primary mission is not to record data about events that are configured as violence against women [24].

Second, in "World Report on violence and health published" by WHO, presents the ten leading causes of death and DALYs (disability adjusted life years) for the year 2000, as well as the rankings for violence-related deaths and DALYs. These rankings are given for all WHO Member States combined and for each of the WHO regions. Deaths and non-fatal injuries are categorically attributed to one underlying cause using the rules and conventions of the International Classification of Diseases. The cause list for the Global Burden of Disease project for 2000 (GBD 2000 project) has four levels of disaggregation and includes 135 specific diseases and injuries. Unintentional and intentional injury categories are defined in terms of external cause codes [25].

Third, the WHO, in collaboration with the United Nations Development Programme (UNDP) and the United Nations Office on Drugs and Crime (UNODC), began developing the "Global status report on violence prevention 2014". It involved systematically gathering data and other information from each country, led by a government-appointed National Data Coordinator. Within each country, individual respondents from ministries of health, justice, education, gender and women, law enforcement and police, children and social development, interior, and (where relevant) nongovernmental organizations, completed a self-administered questionnaire. The questionnaire focused on interpersonal violence including child maltreatment, elder abuse, intimate partner violence, sexual violence, youth violence, gang violence and armed violence, and included questions covering the different areas [26].

In addition, the entropy-weight method showed interesting results and could be applied to other studies in which there are social criteria or variables, which have high level of uncertainty, as the entropy-weight method considers the uncertainty within its analysis [27]. This fact is an advantage regarding to other multi-criteria analysis methods, such as Delphi or AHP [28].

V. CONCLUSION

In Peru, 2016 year it is considered by the Ministry of women and vulnerable populations (MIMP) as the year with more registered femicides until today. In this way, the department of Lambayeque is better positioned in the ranking of no violence against women, since that in 2016 year there were no victims of femicide in this department. In addition, department of Lima, with the largest number of femicides for that year is considered in the range "medium" taking into account the large number of female population that lives in the capital of the Peru.

The top five departments in the ranking of violence against women were: Madre de Dios, Moquegua, Tacna, Tumbes and Ayacucho. In these departments, the risk to women of being violated was very high. Currently, two years later the news of violence against women continues to be a great impact for society as shown in the communication media. The authorities need to take more attention to this problem that has a strong social impact.

Finally, the entropy-weight method, which was used in this article, could be recommended to be applied to other social studies such as: child violence, juvenile delinquency, or depression.

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