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Research Article

Measuring HS in Small, Vulnerable Municipalities: A Quantitative Approach

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Abstract: This article presents a methodological proposal for formulating a Human Security Index (HSI), including information from institutional sources and the inhabitants' perception of security. The developed methodology uses quantitative methods to evaluate HS (Human Security) in small municipalities with large rural areas affected by the confluence of different social and economic problems. Given the security conditions in the area, it was impossible to use a random sampling mechanism. Therefore, the data collected have a sample size that cannot be considered significant enough to make inferences using a frequentist statistics approach. The method to construct the index is illustrated using Miranda's data, a Colombian municipality exposed to decades of armed conflict. With the answers given by 55 interviewees to questions related to the armed conflict such as presence-absence reminders and retained values of violent events, a proposal of 36 indices was made, and two of them were selected for the study, following some statistical criteria. In the construction of one of these selected indices, we used information from binary variables and, for the other index, we used information from count data. The values obtained by both indices for the municipality of Miranda were, respectively, 46.4 and 35.8. According to HS experts, both values can be considered moderate levels in the perception of insecurity by residents of the municipality.

Keywords: Bayes Theorem; Human Security; Index; Latent Variable; Principal Component Analysis

1. Introduction

The concept of Human Security (HS) began as an academic discipline associated with concerns about the responsibility of the State for the living conditions, physical integrity, domestic order and international affairs of each country. Different authors, some of them considering aspects such as living conditions in general, and the presence-absence of violent or dangerous contexts, have established some basic concepts related to human security. The Human Development Report, published by the United Nations Development Program (UNDP) [1], defined the HS from an approach that considers the vulnerability of people and whose objective is to protect the vital nucleus of all human lives under critical threats. This concept of HS consistently establishes long-term human achievement, analyzing threats and causes of insecurity considering seven dimensions: personal, community, political, economic, food, environmental and health, seeking multisectoral responses. According to the same report, in contexts of high insecurity, the measurement of

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HS makes it possible to identify and locate the human insecurities of the population, determine causal relationships between threats and impacts, and provide objective evidence of great value for the implementation of strategic actions to combat root causes of insecurity. For the Harvard Program on Humanitarian Policy and Conflict Research (HPHPCR 2001) [2], the concept of HS is restricted to the reasons that lead to deaths caused by violence associated with armed conflict and criminal actions. The proposal to operationalize the HS concept was to use conventional measures such as the estimated mortality rates for each type of violent source associated with the armed conflict per 100,000 inhabitants. The Human Security Program of the University of British Columbia, Canada prepared a Human Security Report (HSR cited by [2]), analyzing only state-reported information on deaths caused by armed conflict and armed criminal violence. Bajpai [3], one of the first researchers to define HS, establishes that it is related to protection from direct threats to the personal safety and well-being of each individual. King and Murray [4] define human insecurity as a state of generalized poverty, which exists when a human being is rated very low in various domains of well-being. Owen [5] establishes that the definition of HS should include information on diseases, violence, natural disasters and civil conflicts that are the main causes of preventable premature mortality to complement information on mortality rates and other variables. The same author proposes a methodology to measure HS, assuming that "it is the protection of the vital core of all human lives from critical and widespread economic, environmental, health, food, political and personal threats". More recently, Jarmozco [6] developed a definition of HS from an anthropological perspective, which includes the protection/security of individuals and the communities they constitute. In this way, according to the author, a safe state is the one that provides security for its citizens.

In this study, two theoretical approaches were used to develop indices to measure HS: the extended and the restricted approaches [2]. The first approach involves seven security dimensions, analyzing the different situations and considering all of them. The second approach seeks to analyze a situation only considering a few dimensions, which has spawned multiple discussions on the operational definition of the HS due to possible biases when attempting to measure it using a specific type of threats considered fundamental for HS. Many authors have proposed methods to measure the HS, which vary depending on the used definition. Bajpai [3] builds the Human Security Audit (HSA) using indicators on seven dimensions related to the same number of direct threats. They can be measured for a country in local, regional, international, and global levels. King and Murray [4] established three methods to measure the generalized poverty from the information related to four defined domains (health, education, political freedom and democracy), using population indicators and decreasing to individual dimension. Lonergan et al. [7], in the Global Environmental Change and Human Security Project (GECHS) framework, developed an Index of Human Security (IHS) that focuses on a large number of human security threats putting particular interest in some environmental factors. The authors argued for the possible existence of a cumulative causal relationship between environmental changes, social conditions and security. They build the IHS assuming a restricted approach and using information on 16 indicators related to insecurity from different countries' environmental, economic, social, and institutional components. The methodology used to build the IHS was based on complete time series for all indicators in all countries with standardized data to have indicators that take values on the same scale and within the same range, where the index was calculated through cluster analysis.

Hastings [8] relates the HS index to the basic conditions of quality of life for people at home, in the community and in their countries. He proposes a prototype Human Security Index (HSI) for 200 economies in the Asia-Pacific region, calculating the unweighted average value between the Basic Human Development Index and the Social Fabric Index. Werthes et al. [9] created an HSI index for 209 countries, considering the seven dimensions of HS proposed by UNDP. In the construction of the indicator, the number of dimensions was reduced to six. The authors found a high correlation between personal and community dimensions. Therefore, they decided to unify the two dimensions. Finally, Leaning [10] develops a methodology to measure HS starting from the resilient concept obtaining indicators for three psychosocial dimensions.

According to the reviewed literature, all attempts to construct a measure that synthesizes the expression of the human security as a trait present in an area or a population considered large populations (big cities, whole countries, clusters of countries). Usually the construction of the proposed index is based on data obtained from official and government sources, which is possible in countries with efficient official information systems.

In less developed countries, finding efficient and complete information systems to capture official data for all regions in the country is not easy. This fact motivates us to the main goal of this study: to present a methodology to build an SH index for small municipalities exposed to armed conflicts and dangerous conditions with the presence of different violent actors for situations where the access to good quality official information is impossible. The proposed approach considers the development of a quantitative methodology that combines different statistical procedures, some of them used under the frequentist paradigm and others considered under the Bayesian paradigm.

The proposed methodology is illustrated using data collected in Miranda, a small municipality located in Cauca, a department in southwest Colombia, a country rich in natural resources with coasts in the Atlantic and Pacific Oceans and located at the northern tip of South America. In the southwestern area of the country, Northern Cauca is a corridor that enables the connection between the east side of the country and the Pacific Ocean used by diverse armed and criminal groups to transport supplies, men, weapons, and illicit drugs. The estimated population for Colombia in the year 2017 was 41,202 million inhabitants consisting of 52% Afro-Colombians, 18% indigenous, and 30% with no ethnic condition [11]. Three zones characterize the topographic composition of the municipality: the mountainous rural zone, inhabited by peasants and indigenous; the flat rural zone, inhabited by Afro-Colombians; and the urban area. Traditionally, various armed groups have settled in the mountainous rural zone. The municipality is located 47 km from Santiago de Cali, the third largest city of the country. In Colombia, the presence of violent armed conflicts has been constant since the beginning of the 20th century where the country has more control in big cities, neglecting small municipalities and rural zones, which makes the armed conflict experienced in different ways, stronger and more violent in some zones than in other ones.

The northern section of the Cauca department is a region of Colombia with the highest concentrations of conflicts, where insurgent and paramilitary groups have impacted the municipality and its surrounding area since the 1960s. According to Single Registry of Victims, in the period from 1986 to 2016, more than 300 clashes, more than 400 threats, 7,000 displaced people and almost 300 cases of forced disappearances were observed in this region. In addition, during the period from 1986 to 2007, 45 cases of intentional homicide were documented in the municipality, including three or less defenseless people in the same circumstances of time, mode and place (selective homicide). Also, there is the presence of drug trafficking and common crimes [12].

The article is organized as follows: Section 2 presents the proposed methodology for the construction of the HSI. Section 3 introduces an application of the proposed methodology using data from a Colombian municipality (Miranda, Cauca). Section 4 presents the obtained results for the Miranda municipality. Finally, Section 5 discusses the index construction and presents some concluding remarks for the obtained results.

2. Methodology

2.1. HS Definition and Statistical Theoretical Framework

From a statistical perspective, Human Security can be defined as a variable that is not directly observable usually being approximated using some operationalization techniques. There are many variables with this characteristic in nature. Most of them are related to the expression of human traits such as knowledge, depression, perception, and anxiety (among many others). Psychologists generally use the word construct to refer to this type of variable. Statistically speaking, such characteristics are called latent variables. According to Silva [13], a latent variable (also called a synthetic variable) is a function of intermediate variables, each one contributing to quantify some feature of the concept and the magnitude of which is sought to be synthesized. The expression of the latent variables can be quantified and represented using real numbers in a continuous scale (indices or indicators) obtained after applying some operationalization strategy that uses information taken from other observable or directly measurable variables [14,15]. Therefore, it's possible to have an approximation of the construct, but never its genuine quantitative expression.

As an operationally technique used in this work, the "HS" construct is defined considering the restricted approach, including aspects of the HPHPCR 2001 and the Human Security Report (HSR) definitions. In this work, human security is defined as the perception of security of the inhabitants exposed to violent acts that can be done by all or any of different violent actors such as insurgent groups, the army, or ordinary crime. The construct "perception" is defined as the first knowledge of a thing (security) through impressions communicated by the senses [16]. The definition of the construct security is based on the possibility of enjoying a long and healthy life, acquiring knowledge, and having access to the resources necessary to achieve a decent standard of living [17,18]. According to the HS constructed definition, when the individuals are aware of the presence of violent actors and experiment violent acts, both, the individual and collective insecurity perception increases, then, unsafe conditions in the environment are reflected in a collective insecurity perception, which ends up being a proxy for human insecurity in the geographical space where people live.

Operationally, using information obtained from different sources, many violent acts that can occur in an armed conflict can be identified. Sources as the news published in Colombian newspapers, annual reports on violent events and victims in the context of the armed conflict and common crime, published by the Colombian National Police, the National Institute of Legal Medicine and Forensic Sciences, the Single Registry of Victims and the Colombia Information Management and Analysis Unit (UMAIC) for the United Nations System, were visited to establish 16 violent acts: Harassment or guerrilla attacks, injuries from landmines, bombings, homicides, personal injuries or injuries from conflict/fights, forced displacement, kidnapping, extortion, forced disappearance, torture, illegal detention (provisional), threats, terrorism, confrontations in a populated area with civilians, illicit roadblocks and thefts.

2.2. Stages for the construction of the Human Security Index

In general, it is impossible to use inferential statistical methods or usual multivariate procedures to obtain an index when we have small sample sizes and lack of randomness. In this study, a new methodological strategy is proposed to deal with this situation, taking as a support the mathematical statistical theory where a questionnaire with closed questions was applied that includes different types of answers (binary, counts or scales).

2.2.1. Estimation phase

Binary variables (X): The inhabitant's answers to the presence-absence of the violent acts were associated with binary random variables that can be modeled using a Bernoulli distribution. An estimation procedure is considered under a Bayesian approach [19–21], which assumes that observations from the sample are interchangeable, namely, not necessarily independent but identically distributed since all people live in similar security conditions. The probability that one individual answered that he remembered the occurrence of a violent act ($\theta_j = P(X_j = 1)$); $j = 1, 2, ... t$ where t is the number of questions with binary response) was assumed as a parameter of interest (success probability). The success probability is considered under a Bayesian approach as a random variable whose natural behavior can be modeled using a probability distribution (prior distribution). In this case, usually it is assumed a Beta prior distribution for the parameter θ_j, which is very flexible and easy to be used [20,21]. In special, we assume, $\theta_j \sim Beta(1, 1)$ representing that all possible values for the success probabilities have the same probability of occurrence. That is, we are assuming a flat prior distribution for the estimation process. The posterior distribution for the parameter θ_j is obtained using the Bayes formula ($\theta_j | x_j \sim Beta(a_j = x_j + 1, b_j = n - x_j + 1)$ where x_j is the number of individuals who answered that they remembered the occurrence of the $j - sth$ violent act during the observed period and $n - x$ is the number of individuals who answered that they did not remember the violent act ($n =$ number of individuals surveyed). To obtain the estimated probability, a Markov chain of L random numbers distributed $Beta(a, b)$ is simulated using the R software, and the first k (any number) simulated values are eliminated to guarantee the stationarity (burn-in process) of the series. Visual analysis of the histograms of the simulated values are observed and depending on its shape, one of two lost functions can be assumed to get the estimator of interest. When the shape tends to be symmetrical, the squared loss function is considered, and the mean of the simulated values on the final chain (after burn-in) is assumed as the Bayes estimator. If the histogram shows an asymmetrical shape, an absolute loss function must be assumed, and the median of the chain of random numbers is considered as the Bayes estimator.

Discrete variables (counts Y): There are answers for which it is possible to associate a continuous or discrete random variable. If the response is a number of events, a quantitative discrete random variable can be assumed, and the same is understood as a sum of Bernoulli trials that happened in a period of time in similar conditions but that are not independent (the occurrence of an event can depend on other if both events are joined by some circumstance). For that reason, each realization y of the random variable Y can be assumed as an interchangeable Bernoulli trial. The natural behavior of the count variables $Y_j = \sum_{j=1}^{\infty} X_{ij}$ can be represented by a Poisson model, that is, $Y_j \sim Poisson(\mu_j)$. In this case, the parameter to be estimated is $\mu_j = E(Y_j)$, that is the expected number of events that some individuals living in the municipality during the period of interest. As the value of μ (parameter) must be estimated, a procedure similar to that developed with the binary variables is created, and it is assumed that μ is a random variable whose natural behavior can be modeled using a distribution of probability. We assume, $\mu \sim Gamma(d, e)$ which is a conjugate prior distribution, where the hyperparameter d is interpreted as the number of events occurring in a given time and e is the average time elapsed between events. To obtain values for (d and e), the information contained in secondary sources such as official reports or experts' knowledge is used. The posterior distribution obtained using the Bayes formula is a $Gamma$ ($s = d + n\overline{x}$, $t = e + n$) distribution. A large quantity of random numbers is simulated from the posterior distribution, where k of them are used for the burn-in stage; after this burn-in stage, we use the rest of the generated samples to get a Bayesian estimator for the parameter of interest.

2.2.2. Simulation

With the Bayesian estimates obtained in the previous stage, new chains of random numbers are generated using the R package. For binary variables, the Bayesian estimation of the proportion for each binary variable is assumed as the success probability of a Bernoulli trial, and a quantity of m repetitions are carried out. Similarly, for any other type of variable, a distributional form must be found, the parameters to be estimated using the data and prior distributions, and to use the estimations as parameters for simulating m realizations of the variable. Since different responses are obtained for each individual, it is very important to evaluate the autocorrelation between the responses in the same individual. Therefore, the correlations matrix between pairs of variables must be estimated using the sample data and the same is used as an input to run the *gerCorGen* command of the statistical R program [22]. This command generates correlated data via normal copula with a multivariate distribution from the specification of the distribution parameter and the data's correlation structure. Simulation via copula guarantees that the data with which the HSI will be constructed, maintain the structural characteristics of the sample data obtained in the fieldwork. The simulated data includes information from secondary sources.

2.2.3. Multivariate statistical methods

An evaluation of the entire data array should be made to identify questions with low frequencies of response, when compared to the other variables, since small amounts of observations in the variables affect the multivariate procedure development. Therefore, it is advisable to exclude those variables with a very low frequency of occurrence before running principal components analysis (PCA) [23–25]. Before carrying out the procedure, experts can be consulted on the importance of each violent event considered on the human security construct. This knowledge is reflected in the final weights obtained after using the statistical method. With the results of the statistical procedure, it is obtained the eigenvector associated with the first principal component, which contains the weights of each violent event. Given the theoretical characteristics of the HS construct, it is expected that the weights of all violent events must be positive, so the occurrence of a violent event increases human insecurity. With the simulated data, the correlations matrix is evaluated for quantitative variables and categorical variables to establish the relationship shape through the correlation coefficient sign (direct=positive or inverse=negative). This procedure allows identifying a size factor (when all relationships between variables are in the same sense). When there is a size factor in the observed data, the index constructed using PCA shows a relationship of increase or decrease of all violent events simultaneously. When there is no size factor, the index will show different relationships between the variables, where some factors would be added to the quantification of the HS and other factors would be subtracted.

If a size factor (regardless of the type of variable) is present in the data, the weight ($p_j; = 1, 2, ..., m$) of the violent event j, is computed by transforming the weights of the eigenvector associated with the first principal component (u_1), using the equation:

$$p_i = \frac{u_{i1}}{\sum_{j=1}^{m} u_{j1}} * 100 \tag{1}$$

To obtain the opinion contribution of a surveyed individual, the weight of the violent act (p_j) is multiplied by the numerical quantity (x_{jk}) assigned to the person's response to the question that evaluates either by the memory or by the number of times the person remembers that the violent event occurred. Then, for a k-th individual

$$I_k = \sum_{j=1}^{m} p_j x_{jk} \tag{2}$$

The final value of the HSI for the municipality will be an average value (median, mode, or some kind of average) obtained from the distribution of all values for $I_k K = 1, 2, ..., n$, ($I^{+1} = g(I_k)$) where n is the number of surveyed individuals.

If it is impossible to assume the existence of a size factor, Becerra [24] developed a proposal to compute indices. To scores associated with quantitative variables (in this case, the discrete variables), which seeks to express the first principal component with scores greater than or equal to zero, we should follow the steps:

- The PCA is carried out with quantitative variables obtaining the eigenvector associated with the first component (u_1). The answers to the questions are standardized by obtaining m variables $z_{jk} = \frac{x_{jk} - \mu_j}{\sigma_j}$, where $\mu_j = \frac{\sum_{k=1}^{n} x_{jk}}{n}$ and $\sigma_j = \sqrt{\frac{\sum_{k=1}^{n}(x_{jk} - \mu_j)^2}{n-1}} j = 1, 2, ...m$ and the variable score-factor $T_{jk} = |z_{jk} - minz_j| * u_{j1}$ is constructed.
- The variables $V_{1j} = max(T_{jk})$ and $V_2 = \sum_{j=1}^{m} V_{1j}$ are computed, and the weights for the observable variables that make up the index with them are obtained. Thus,

$$p_j = \frac{V_{1j}}{V_2} * 100 \tag{3}$$

- For each individual, the contribution to the index would be given by:

$$I_k = \sum_{j=1}^{m} p_j x_{jk} \tag{4}$$

To scores associated with binary variables, we follow the steps:

- Perform the PCA and obtain the eigenvector associated with the first $\boldsymbol{u_1}$ component from where it is obtained the factorial weights for the h^{th} ($\boldsymbol{h = 1, 2}$) category that makes up each j^{th} variable (remember that each variable has just two categories, one of them considered as a success). Select the minimum weight between the two categories ($\boldsymbol{Q_j = min(u_{jh_1})}$) and do $\boldsymbol{R_{jh} = u_{jh_1} - Q_j}$
- Obtain $\boldsymbol{W_{1j} = max(u_{jh_1})}$ and $\boldsymbol{W_2 = \sum_{j=1}^{m} W_{1j}}$ and the weights for the observable variables that produces the index, using:

$$p_{jh} = \frac{R_{jh}}{W_2} * 100 \tag{5}$$

- For each individual, the contribution to the index is given by:

$$I_k = \sum_{j=1}^{m} \sum_{h=1}^{qj} p_{jh} x_{jhk} \tag{6}$$

The final value of the HSI for the municipality is an average value (median, mode, or some kind of average) obtained from the distribution of the all values of $I_k K = 1, 2, ..., n$, ($I^{+2} = g(I_k)$) being n the number of surveyed individuals. Higher values for the index should be interpreted as high levels of Human Insecurity in the municipality.

2.3. Selection of the Best Index

After applying the proposed methodology, many different indices can be obtained regardless of the type of the variable evaluated in the field. In situations like this, we propose selecting the best index through the use of the following heuristic process:

- Obtain I_k with the simulated data.

- Obtain the value of I^{+1} or I^{+2} and assume it as the reference value (I_r) of the index for the municipality. If I^{+1} is calculated, this index does not have a pre-established maximum value since there is no upper limit for the number of violent events that occurred in the municipality during the study period, so, it is necessary to transform the value obtained and express it on a scale that takes values in the interval [0-100], as follows:

$$I_r^+ = \frac{I_k^{+1} - min(I_k^{+1})}{max(I_k^{+1}) - min(I_k^{+1})} * 100 \quad k = 1, 2, ..., n \tag{7}$$

- Draw a random sample of 80% of the simulated database, run the PCA analysis and obtain the value of I^+ with said sample. Repeat this procedure using resampling techniques a large number $f = 1, 2, ..., L$ of times. For details, see Beasley and Rogers [26]. In the end, there must be L values of the HSI (I_f^+), each one obtained with a different sample taken with replacement from the sample that includes the 80% of the original sample of simulated data.
- Compute an empirical approach for the estimation error (ee_f) using the equation: $ee_f = I_r^+ - I_f^+$. Here you must have L values of ee_f.
- Compute the average value for all obtained ee_f so that the estimation error can be approximated as $EE = \tau(ee_f)$.

Finally, the index with the lowest observed estimation error (EE) is selected as the best one.

3. Data from a Colombian Municipality Exposed for Decades to Armed Conflict

The information from the Miranda municipality in Colombia was used to illustrate the proposed methodology to build an HS index. Miranda is a small Colombian city with around 40000 inhabitants, exposed for decades to armed conflict. The civilian population coexists with armed actors, the army, common criminals, and drug traffickers.

3.1. Information Sources, Sample, and Variables

The criminal observatory of the Colombian National Police was the first official source consulted to obtain the data to be used in this study. As this criminal observatory is a national institution, data on crime in Miranda were requested, in particular monthly information on homicides, personal injuries, domestic violence, sexual violence, extortion and theft, during the period 2012-2016. Also, the National Institute of Legal Medicine and Forensic Sciences that is a public entity that manages and controls the legal medicine and forensic sciences system in Colombia was consulted to get the data set. These government institutions provide data on homicides and interpersonal violence in Colombia. These data sets are of public domain, available in the website link https://www.medicinalegal.gov.co/cifras-estadisticas/forensis.

The Single Registry of Victims (Registro Único de Victimas, RUV, in Spanish) is an information system created by the Colombian government as Victims Law (Law 1448 of 2011) to centralize and concentrate on a single point, the information about the armed conflict victims who demand attention and integral reparation by the state. The RUV records information about 11 victimizing acts: terrorist acts, threats, homicide, sexual violence, forced disappearance, forced displacement, landmines, kidnapping, and illegal recruitment. The information can be accessed using the link https://www.unidadvictimas.gov.co/es/registro-unico-de-victimas-ruv/37394.

The last consulted source was the platform of the Colombian Information Management and Analysis Unit (UMAIC) for the United Nations System. This system contains recorded documentary data of events associated with the Colombian armed conflict. It can be consulted in https://data.humdata.org/dataset/4f37343a-82ac-49f8-b4a8-3dc3e067a6cb.

A closed-choice survey including questions about the presence-absence and count of times that a person remembers that any of 16 violent events occurred within a specific period was constructed to be applied in the period from July to August 2017. A pilot study conducted with three inhabitants of the municipality to evaluate the questionnaire field performance allowed identifying two violent events not considered in the initial version. In this way, the final survey includes 18 violent acts. Additionally, we also used the information published by organizations or institutes that report statistics on the type of violent event and the number of times it occurred in the municipality.

In the context of focus groups, 18 forms were fulfilled. The remaining 37 were completed in-home visits; a non-random sample of 55 individuals who lived in the municipality since 2012 was obtained for the present study. The first contact was established through relatives of one of the researchers born in the city, and they contacted other inhabitants (neighbors and friends). The research purpose and the importance of their participation were presented to all participants, and they signed an informed consent. Random sampling was not possible since there was the risk of interacting with people belonging to armed groups. The questionnaire was about residence area (mountainous rural area, flat rural area, and urban area), participants feeling they were at risk of suffering some violent act, whether they remembered or not the occurrence of any of the 18 violent events related to the Colombian armed conflict during 2010-2013, and the frequency with which they remembered that such event had occurred (infrequent, (1-2 times), frequent (3-5 times), and very frequent, (more than five times). A copy of the questionnaire is available in an appendix at the end of the manuscript. An individual could remember if the violent event occurred and how many times it occurred. Besides this situation, there were cases in which an individual remembered the occurrence of the violent act, but he did not remember the number of times it happened.

Two variables were of interest to build the index: the occurrence of the violent event (binary variable $X_j j = 1, 2, ..., 18$) and the number of times that the same occurred during the period remembered by an individual (quantitative discrete variable $Y_{j,} j = 1, 2, ..., 18$). Additionally, the question about the feeling of safety was operationalized in a binary random variable that took the value 1 if the individual answered not feeling safe.

Before the simulation stage, it was necessary to include the number of violent acts that were not reported by the people, either because they did not remember the event's occurrence or they remembered it, but not the number of times occurring. In this latter case, for each violent act, the missing amount was imputed [27], which generated a random number according to the frequency reported by the persons in the questionnaire (infrequent, frequent, very frequent). For example, if the person indicated that the violent event j was frequent (3-5 times), a random number between 3 and 5 was assigned. For binary variables, missing data in the inhabitants' response regarding whether or not they remember the occurrence of the violent act j, was imputed using the answers mode, that is, if for the violent act j the proportion of people who remembered the occurrence of that act was greater than those who did not remember it, a value equal to 1 was imputed, indicating that the person remember of the occurrence. The imputation was made to find the sample data correlation matrix used in the simulation process (The matrix had 55 rows and 36 columns, where 150 observations were imputed). The distribution of imputed data among the variables is shown in Table A1 in the Appendix.

To carry out the simulation study, it was considered simulating data from the general population, from the population by residence area, from the population that feels at risk of suffering some violent event (insecure), and from the population that does not feel at risk (secure). For each scenario, we first proposed to simulate a sample of 55 residents (size of the studied sample). From this information, we further assumed a sample of 1,000 inhabitants (a generated sample).

The expected amounts of violent events per period and the proportions of individuals who remember the violent event were estimated under a Bayesian approach. In this way, the information contained in the institutional sources was used to construct prior distributions for the parameters of interest to combine with the information from the data obtained of the survey responses given by the inhabitants. The average and the variance of the number of events reported as occurring in any periods reported by the sources (some sources did not contain information about all considered violent events) were obtained, and an equations system was solved after matching those values with the theoretical forms for the variance and the expected value of a Gamma distribution assumed as prior for the parameters of the proposed model.

The data of people who lived in the mountainous and flat rural areas were combined as data from the rural areas. The estimated correlation matrices were obtained for each group of observations using Spearman correlation coefficients for quantitative variables and tetrachoric correlation coefficients for dichotomous variables. With the simulated data obtained using a copula function used to capture the possible dependence structure between the responses, the HSI was constructed for the quantitative variables (number of occurrences) and binary variables (remembering or not occurrences. Two HS experts were consulted to classify the violent events. They classified the violent events according to the type of crime they represented: against life and personal integrity, against individual liberty, against public security, and against economic assets. A weight was assigned to each type of crime according to its effect on HS and the same occurred for violent acts of each type of crime. The sum of weights assigned to the violent events of every kind of crime totalizes 100%. The proposal to include these weights in the PCA was to multiply the weights assigned to each violent act by the weight of their respective type of crime; for example, for the violent act of "Injured by landmines", the weight assigned by the expert (17%) was multiplied by the weight of the crime (32%), which resulted in a general weighting of 5.44%. This weight was included in the PCA procedure, so, the final weight for each variable is a ponderation between the weight computed by the procedure (PCA) using the sample data and the weights assigned by the expert. In the construction of some of the HIS indices, the variables "Torture" and "Theft of crops" were excluded due to their low frequency of occurrence in the responses. The violent events considered in the survey and the weights assigned by two HS experts to each violent event before the use of the PCA procedure are presented in Table 1. Finally, 36 different indices were built; 24 indices using discrete quantitative variables and 12 using dichotomous variables as input. Table 2 summarizes each index proposal and its characteristics according to the simulation scenario considered for its construction.

Table 1. Weights allocated by experts to each dimension of the crime, each violent act, and the PCA's weight. (*Percentage in relation to the weights of each dimension).

Dimension (classification of crimes)	Violent event	Weight of each dimension	Weight assigned to each violent event*	Weight used in the PCA procedure
Crimes against life and personal integrity	Injured by landmines	32%	17%	5.44%
	Homicides		30%	9.60%
	Personal injuries or wounded by conflicts or disputes		10%	3.2%
	Threats		3%	0.96%
	Torture		15%	4.8%
	Forced displacement		25%	8%
Crimes against personal freedom	Abduction	29%	40%	11.6%
	Forced disappearance		50%	14.5%
	Unlawful detention		5%	1.45%
	Illegal checkpoints		5%	1.45%
Crimes against public security	Harassment or seizure of power by the guerrilla	24%	25%	6%
	Attacks with explosives		25%	6%
	Terrorism		25%	6%
	Conflicts in populated zones		25%	6%
Crimes against the economic assets	Extorsion	15%	25%	3.75%
	Theft		25%	3.75%
	Cattle rustling		25%	3.75%
	Crop theft		25%	3.75%

Table 2. Considered scenarios for the construction of the HSI according to expert judgment, type of variable, survey data, and simulated sample size.

Index proposal		Type of Variable considered	Data used to obtain correlation structure simulated		Number of inhabitants	Variables included in the index
Excluding expert judgment	With expert judgment					
1	19	Number of occurrences of violent events (Quantitative variable)	General data (all the responses of 55 individuals)		55	All variables
2	20				1000	
3	21				55	Excluding Torture and Crop Theft
4	22				1000	
5	23		Data filtered by area of residence	Rural area	55	Excluding Crop Theft
6	24				1000	
7	25			Urban zone	55	Excluding Torture and Crop Theft
8	26				1000	
9	27		Data filtered by security perception	Not secure	55	All variables
10	28				1000	
11	29			Secure	55	Excluding Torture and Crop Theft
12	30				1000	
13	31	Memory of occurrence of violent events (Dichotomous variables)	General data		55	Excluding Torture and Crop Theft
14	32				1000	
15	33		Data filtered by security perception	Not secure	55	Excluding Torture and Crop Theft
16	34				1000	
17	35			Secure	55	Excluding Torture and Crop Theft
18	36				1000	

The procedure to obtain the indices includes the construction of an equation that adds the product between the weights and the value assigned to the answer given by an individual to each of the questions in the survey. Each name of a violent event was coded according to the type of variable, where Y_j is the number of times of occurrence of the violent event j, for all j from 1 to 18 and X_m is the binary variable that identifies whether an individual remembers the occurrence of the respective violent event for all m from 1 to 16.

An empirical process for validation was carried out with each of the 36 indices. For each index, its value was initially obtained by the simulated number of individuals in the municipality (in some cases, 1,000 individuals and in other cases, 55 individuals). Thus, the median value of the individual values was obtained as an approximation to the municipal index (reference value). This procedure was applied to each of the 36 indices. A random sample of 80% of the simulated data was obtained (800 individuals in samples of 1,000 and 44 individuals in samples of 55) to compute each one of the HIS indices. The procedure was repeated 1,000 times to obtain 1,000 estimates of each HSI. Then, the difference between the 1,000 values obtained and the reference value was calculated. Finally, an approximation of the sampling error associated with the index j (j=1,2, ..., 36) was obtained through the median of the differences.

4. Results

Among the 55 individuals in the sample, 60% (33) were men, 74.1% (41) were residents in the urban area, 16.7% (9) were residents in a flat rural area, and the remaining 9.3% (5) were inhabitants of the rural mountainous area. Twenty-six people (47%) said they had been affected by a violent event at some time in their lives. The median age was 41 years old (Interquartile Rank 34 to 53), and the median of the time living in the municipality was 27.5 years (IR 17 to 40). At the moment of the survey, 51.9% (28) of the participants reported feeling at risk of suffering a violent event. Only one person did not answer the question. In the construction of the index using data from binary variables, prior distributions for the parameters of the model were obtained under the Laplace principle (Uniform (0,1) distributions), where the posterior distributions are given by $Beta(a, b)$ distributions (Table A1, Appendix). The prior and posterior distributions are presented in Table A2 in the appendix for the index developed using information from count data. Tables 3 and 4 report the descriptive statistics and the estimation errors obtained via simulation for the set of indices constructed during the process.

Table 3. Descriptive statistics and estimation errors for the HSI constructed using 1000 simulated count data.

	Index No.	Min	Max	Mean	Median deviation	Standard	EE
Without expert judgment	1	25.48	70.2	47.35	47.49	7.19	6.28
	2	35.49	58.07	46.39	46.48	3.61	2.51
	3	27.72	68.75	47.64	47.66	7.34	8.98
	4	35.36	61.25	46.7	46.75	3.63	2.62
	5	28.62	74.33	49.51	49.25	7.45	5.95
	6	37.85	60.85	49.32	49.69	3.79	3.91
	7	25.77	71.47	47.31	47.46	7.26	7.03
	8	33.36	57.50	46.19	46.26	3.70	2.44
	9	26.98	76.10	49.60	48.79	7.37	4.25
	10	37.54	62.69	49.04	49.23	3.75	2.51
	11	24.35	67.92	49.16	48.94	7.17	9.55
	12	35.50	63.10	49.18	49.20	3.74	2.43
With expert judgment	19	25.87	69.37	47.24	47.23	7.16	5.18
	20	**35.55**	**59.43**	**46.36**	**46.45**	**3.60**	**2.20**
	21	26.92	69.17	47.62	47.69	7.35	8.28
	22	35.17	60.95	46.70	46.73	3.63	3.41
	23	27.90	72.88	49.43	49.21	7.46	6.47
	24	35.77	62.81	49.25	49.33	3.71	3.98
	25	25.99	70.73	47.39	47.39	7.27	6.10
	26	33.40	57.98	46.37	46.49	3.72	2.21
	27	25.65	75.89	49.51	49.53	7.50	7.67
	28	36.08	61.69	49.12	49.18	3.75	2.79
	29	24.84	71.68	49.34	49.34	7.12	8.78
	30	34.52	61.45	48.93	48.90	3.83	9.48

Table 4. Descriptive statistics and estimation errors for the HSI constructed using 1000 simulated binary data.

	Index No.	Min	Max	Mean	Median	Standard deviation	EE
Without expert judgment	13	21.03	56.26	36.80	36.31	5.58	6.47
	14	32.67	40.15	36.62	36.54	1.20	5.51
	15	34.07	68.15	50.87	50.63	5.01	6.40
	16	49.71	56.83	53.42	53.75	0.88	4.18
	17	31.61	67.49	47.06	46.79	5.41	7.91
	18	43.11	51.15	46.24	45.97	1.31	4.98
With expert judgment	31	20.28	54.3	35.23	34.81	5.37	6.47
	32	**31.9**	**39.53**	**35.77**	**35.78**	**0.99**	**3.34**
	33	34.27	66.79	48.97	48.48	5.05	6.23
	34	47.18	54.34	50.54	50.59	1.16	4.07
	35	31.85	67.32	47.21	47.03	5.51	7.45
	36	41.84	50.6	46.20	46.22	1.18	4.54

The HSI was constructed using the number of occurrences of violent events where the smallest error among the 24 indices was given by the index number 20 with an error of 2.20 units (Table 4). The PCA assumed to obtain this index with expert judgment used 1,000 simulated data for the number of occurrences of the 18 violent events, using a correlation structure obtained from the observable data. The HSI constructed considering the variables referring to the memory of the occurrence of violent events, which had the smallest error, was the index number 32 with an error equal to 3.34 units (Table 5). Again, this index was developed using the PCA considering the expert judgment and using the simulation of 1,000 individuals who reported remembering or not the occurrence of 16 violent acts.

4.1. Details of the Two Selected Indices

4.1.1. Count Data

From the analysis of correlations obtained for the HIS constructed with the numbers of remembered violent events (HSI_{20}), it was found that the violent events with the highest correlation values correspond to the pairs formed between harassment and attacks with explosive devices (r_{1-3}=0,6); injuries caused by landmines and forced displacement (r_{2-6}=0,51); attacks with explosive devices and terrorism (r_{3-13}=0,52); homicides and forced disappearance, illegal retention, terrorism, thefts (r_{4-9}=0,55, r_{4-11}=0,5, r_{4-13}=0,54 and r_{4-16}=0,52, respectively); personal injuries and extortion, threats, terrorism, illegal roadblocks, rustling (r_{5-8}=0,66, r_{5-12}=0,64, r_{5-13}=0,51, r_{5-15}=0,68 and r_{5-17}=0,6, respectively); forced displacement and forced disappearance, torture, illegal retention, terrorism, theft, theft of crops (r_{6-9}=0.87, r_{6-10}=0,88, r_{6-11}= 0,61, r_{6-13}=0,7, r_{6-16}=0,79 and r_{6-18}=0,72, respectively); extortion and threats, illegal roadblocks (r_{8-12}=0,62, r_{8-15}=0,62), forced disappearance and torture, illegal roadblocks, terrorism, theft, theft of crops (r_{9-10}=0,88, r_{9-15}=0,76, r_{9-13}=0,8, r_{9-16}=0,86 and r_{9-18}=0,83, respectively). The fitted PCA shows that, the first two components collected 60.22% of the variability of the data and no size factor was observed. The first factorial axis was formed by cattle rustling (X_{17}), threats (X_{12}), personal injuries (X_5), illegal roadblocks (X_{15}) and extortion (X_8), Table 5.

Table 5. Weights associated the HSI* using quantitative variable.

Violent event	PCA weights	Transformed weights
Harassment or seizure of power by the guerrilla	0.62	3.47
Injured by landmines	0.79	4.43
Attacks with explosives	0.88	4.91
Homicides	0.74	4.13
Personal injuries or wounded by conflicts or disputes	1.00	5.62
Forced displacement	1.08	6.03
Abduction	0.80	4.50
Extortion	0.93	5.19
Forced disappearance	1.13	6.30
Torture	0.92	5.15
Unlawful detention	1.36	7.63
Threats	1.23	6.87
Terrorism	1.30	7.30
Conflicts in populated zones	0.87	4.88
Illegal checkpoints	1.05	5.89
Theft	1.14	6.40
Cattle rustling	1.16	6.52
Crop theft	0.85	4.77

*HSI_{20} selected when worked with 1000 simulated count data

The following equation was constructed for the HSI using the transformed weights:

$$HSI = 3,47 * x_1 + 4,43 * x_2 + 4,91 * x_3 + 4,13 * x_4 + 5,62 * x_5 + 6,03x_6 + 4,50 * x_7 + 5,19x_8 + 6,30 * x_9 + 5,15 * x_{10} + 7,63 * x_{11} + 6,87 * x_{12} + 7,30 * x_{13} + 4,88 * x_{14} + 5,89 * x_{15} + 6,40 * x_{16} + 6,52 * x_{17} + 4,77 * x_{18} \quad (8)$$

Observing equation 8 and based on the number of violent events remembered by the people, it can be said that the events that contribute most to human insecurity in the studied municipality are illegal retention X_{11} (7.63%), terrorism X_{13} (7.30%), threats X_{12} (6.87%), cattle rustling or theft X_{17} (6.52%), theft X_{16} (6.41%), forced disappearance X_9 (6.30%) and forced displacement X_6 (6.03) %. The events that contribute less to human insecurity are harassment X_1 (3.47%), homicides X_4 (4.13%), injuries by landmines X_2 (4.43%) and kidnapping X_7 (4.50). Violent acts such as illegal detention, threats, cattle rustling, or theft, which were considered of low power by the experts, had an important weight in the HSI due to its high correlation with the other violent acts. In the case of homicides and kidnapping weighted significantly by the experts consulted, they presented little weighting in the HSI obtained. This result is most likely due to the same argument. To understand how HSI is computed, let's assume that the questionnaire about the number of occurrences of the 18 violent events is applied to an individual. For this individual, there were three harassments, two attacks with explosive devices, 50 homicides, 30 personal injuries, one kidnapping, 100 victims of forced disappearances, five confrontations, and 80 robberies. The subject says that no more violent acts were observed. For that specific individual, the HSI takes the following value:

$$HSI = 3,47 * (3) + 4,43 * (0) + 4,91 * (2) + 4,13 * (50) + 5,62 * (30) + 6,03(0) + 4,50 * (1) + 5,19(0) + 6,30 * (100) + 5,15 * (0) + 7,63 * (0) + 6,87 * (0) + 7,30 * (0) + 4,88 * (5) + 5,89 * (0) + 6,40 * (80) + 6,52 * (0) + 4,77 * (0) = 1566,29 \quad (9)$$

The measurement of the HSI for the individual in this example is 1566 (decimals do not make a difference). If the minimum observed score among the whole group of surveyed individuals is 1254, and the maximum is 1624, the standardized value for the specific individual will be:

$$\text{Individual Standardized } HSI = \frac{1566 - 1254}{1624 - 1254} * 100 = 84,3 \quad (10)$$

The HSI for the municipality can be computed using both the raw scores and the standardized scores. In the same hypothetical example, assuming the value 1580 as the median of the scores, the standardized HSI for the municipality is 88,1. With the data of the 55 individuals surveyed in the municipality of Miranda, the estimated standardized HSI is **46.4** with a minimum value of 35.6 and a maximum value of 59.4 (standard deviation of 3.60).

4.1.2. Binary data

For the construction of HSI_{32} from the memories of the municipality inhabitants about the occurrence of violent events, the tetra choric correlation matrix was analyzed and it was observed that violent events with higher correlation values correspond to the pairs formed by harassment and attacks with explosive devices, illegal retention, confrontations, illegal roadblocks ($r_{1-3} = 0,52$, $r_{1-10} = 0,55$, $r_{1-13} = 0,59$ and $r_{1-14} = 0,5$, respectively); injuries by landmines and illegal roadblocks, confrontations, illegal roadblocks ($r_{2-10} = 0,61$, $r_{1-13} = 0,57$ and $r_{2-14} = 0,51$, respectively); attacks with explosive devices and homicides, personal injuries, extortion, illegal retention, threats, terrorism, illegal roadblocks, thefts ($r_{3-4} = 0,51$, $r_{3-11} = 0,5$, $r_{3-8} = 0,61$, $r_{3-10} = 0,64$, $r_{3-11} = 0,75$, $r_{3-12} = 0,66$, $r_{3-14} = 0,54$ and $r_{3-15} = 0,51$, respectively); homicides and personal injuries, threats, thefts ($r_{4-5} = 0,71$, $r_{4-11} = 0,56$ and $r_{4-15} = 0,67$, respectively); personal injuries and extortion, illegal retention, threats, thefts ($r_{5-8} = 0,52$, $r_{5-10} = 0,59$, $r_{5-11} = 0,73$ and $r_{5-15} = 0,7$, respectively); forced disappearance and forced displacement, extortion, illegal retention, threats, illegal roadblocks ($r_{9-6} = 0,65$, $r_{9-8} = 0,65$, $r_{9-11} = 0,53$ and $r_{9-14} = 0,59$, respectively); theft and kidnapping, extortion, threats ($r_{15-7} = 0,55$, $r_{15-8} = 0,56$ and $r_{15-11} = 0,73$, respectively).

The first two components of the PCA contained 40.14% of the data variability. For all the pairs of violent events, the correlations are expressed in only one direction; thus, the factor size is present. There were two groups of violent events that indicate a highly significant correlation between occurrences of each group, one consisting of confrontations Y_{13}, landmine injuries Y_2, forced displacement Y_6, harassment Y_1, kidnapping Y_7, cattle rustling Y_7, forced disappearance Y_9, illegal roadblocks Y_{14} and illegal retention Y_{10} and the other one is formed by the threat variables Y_{11}, attacks with explosive devices Y_3, personal injuries Y_5, thefts Y_{15}, homicides Y_4, extortion Y_8 and terrorism Y_{12}. With the weights associated with the first principal component (see Table 6), the equation for the HSI constructed is:

$$HSI = 4,74 * y_1 + 5,27 * y_2 + 6,64 * y_3 + 3,91 * y_4 + 5,9 * y_5 + 5,85 y_6 + 6,83 * y_7 + 9,3 y_8 + 6,39 * y_9 + 8,7 * y_{10} + 8,7 * y_{11} + 4,77 * y_{12} + 3,99 * y_{13} + 7,98 * y_{14} + 5,87 * y_{15} + 5,16 * y_{16} \quad (11)$$

Table 6. Weights associated with the HSI* using binary data.

Violent event	Factorial axis 1	Transformed weights
Harassment or seizure of power by the guerrilla	0.71	4.74
Injured by landmines	0.79	5.27
Attacks with explosives	1.00	6.64
Homicides	0.59	3.91
Personal injuries or wounded by conflicts or disputes	0.89	5.9
Forced displacement	0.88	5.85
Abduction	1.02	6.83
Extortion	1.39	9.3
Forced disappearance	0.96	6.39
Unlawful detention	1.30	8.7
Threats	1.30	8.7
Terrorism	0.72	4.77
Conflicts in populated zones	0.60	3.99
Illegal checkpoints	1.20	7.98
Theft	0.88	5.87
Cattle rustling	0.77	5.16

*HSI_{32} selected when worked with 1000 simulated binary data

Some of the factors with greater weight for human security in the municipality are extortion Y_8 (9.30%), threats Y_{10} (8.7%), illegal retention Y_{11} (8.7%), illegal roadblocks Y_{14} (7.98%), kidnapping Y_7 (6.83%), attacks with explosive devices Y_3 (6.64%), forced disappearance Y_9 (6.39%), personal injuries Y_5 (5.90%) and thefts Y_{15} (5.87%); and those with lower weight are homicides Y_4 (3.91%), confrontations Y_{13} (3.99%), harassment Y_1 (4.74%) and terrorism Y_{12} (4.77%).

To illustrate how the HIS work, let's assume that an affirmative or negative response is obtained as to whether the individual remembers, or not, the occurrence of 16 violent acts for a sample or population of k individuals. Following a similar procedure used for the HSI example constructed through the number of the occurrences, an individual remembers the occurrence of harassment, explosive device attacks, homicides, personal injuries, kidnapping, victims of forced disappearances, confrontations, and thefts does not remember any other violent event. The HSI value for that individual takes the following value:

$$HII = 4,74 * (1) + 5,27 * (0) + 6,64 * (1) + 3,9 * (1) + 5,9 * (1) + 5,85(0) + 6,83 * (1) + 9,3(0) + 6,39 * (1) + 8,7 * (0) + 8,7 * (0) + 4,77 * (0) + 3,99 * (1) + 7,98 * (0) + 5,87 * (1) + 5,16 * (0) = 44,26 \quad (12)$$

The value of the HSI for the individual in this example is 44.2. In this case, the result is obtained on a standardized scale where it was not necessary to have a transformation of the obtained value. Subsequently, the HSI value for each individual must be calculated, and then the HSI value for the municipality is calculated using the median of the k data. For the Miranda municipality, the human security was computed given the value 35.8 (minimum 31.9, maximum 39.53, and standard deviation of 0.99).

5. Discussion

Since the concept of Human Security emerged, multiple methodological proposals have been prepared to make it operational. According to Owen [4], the measuring concepts such as HS are complex because the measuring term is challenging to apply when the subject to be measured is qualitative and not directly observable. Also, defining a concept like HS necessarily implies establishing a de facto list of what is and is not human security which is not easy given the subjectivity associated. Different authors such as Owen [5], Lonergan [7], and Leaning [10] have proposed both theoretical definitions for the HS and methodological strategies to measure it using quantitative approaches that take indicators measured in different metrics to obtain a unique standardized index. The performance of the methodological approach depends on both conceptual and operational constructed definitions. These authors use the time series of population indicators like rates and statistical methods such as regression models or cluster analysis to obtain the final index form. However, these approaches have a strong limitation; they depend on official and government information systems, which in many developed countries work pretty well but in most underdeveloped countries, it is impossible to access good-quality official data.

As the novelty of this study, a new approach to measure HS assuming the limited theoretical paradigm was proposed. It focuses on the intimidations and events that threaten the life and well-being of people, directly or perceived, in an area traditionally affected by armed conflict, regardless of the agent of these threats. The construction of the index implies the use of different statistical procedures under both frequentist and Bayesian paradigms. It uses information obtained from primary and secondary sources, which can represent a novel proposal. The proposed method enabled human security measurement, first by considering institutional sources data, which may have quality problems or even not be available (generally, it can be incomplete and inaccurate); and also including the opinion and memories of those who suffer from direct threats to their welfare because of the presence of armed conflict. Unlike the works found in the literature review, this approach starts by defining the perception constructed by the Gestalt [16]. This definition was adapted to contextual conditions within which the people live in a geographical area. It considered metrics associated with remembering the presence of violent acts and their amount during a period by the individuals in the population. The partial or incomplete data of different official sources are also considered to obtain more robust information used as input for the index construction.

The latent variables and the interval scale theoretical frameworks are used to handle the difficulty of quantifying the HS. A review made by Bullen [28] about latent variables and their uses is a helpful source for understanding the concept in psychology, social sciences, and statistical modeling. Assuming the HS as a latent variable allows support from mathematical, probabilistic and statistical theory to construct a metric to approximate the presence of threats to human life in a geographical area. To measure latent variables, the interval scale [29] and the index [13] statistical concepts are used to obtain approaches that quantify the expression of the variable using real numbers. Operationally, the methodology starts with a conceptual definition of HS adapted to the contextual conditions associated with the geographical area where the index will be used. Some Bayesian paradigm theoretical concepts as interchangeability in field observations and randomness of the statistical model parameters [19,20] are used to handle the difficulty to obtain primary source data (survey) that meet the statistics theoretical assumptions (for instance, independent and identically distributed observations). The use of the cited Bayesian concepts offers a framework for generalization. It considers the parameters as random variables and the sample data as fixed observations, randomizing the statistical model used for the estimation process previous to the simulation stage. The multivariate statistical methods such as principal component analysis (PCA), the multiple correspondence analysis (MCA), and the multiple factor analysis (MFA), among others, are helpful techniques for working with data sets that contain large numbers of variables [23,24]. The multivariate methods allow reaching different purposes depending on the goal that motivates the obtaining of the data. In measuring latent variables, the MFA is commonly used to approach the level of expression of the latent variable utilizing the information about it contained in observable variables [28]. The procedure estimates the weight that each observable variable has on the latent variable, and it is used to build a mathematical function (weighted sum) that represents with real numbers the expression of the unobservable variable [13]. According to Bajpai [3], a measure of HS must be valid and reliable so that the same can be used to map the human conditions in a region. In a sense expressed by the author, the validity and reliability are strongly associated with measures of HS for countries or big cities using official information. The constructed index in this work is not free from having to meet these two conditions. For that reason, in this case, the theoretical support from the sciences such as mathematics, probability, and statistics makes the proposed methodology valid and reliable to construct indices considering the difficulties of obtaining data that meet assumptions when the same are collected in the field under unsafe conditions. Using prior distributions for the parameters of the proposed model in the Bayesian estimation process guarantees the generalizability of the model that supports the method. On the other hand, to ensure reliability conditions, data assuming probability distributions that include information about the contextual characteristics were simulated, and resampling methods were also used.

Given the characteristics of the targeted area by the constructed HSI and their problems, the development of this type of indices contributes to broadening the discussion about how the concept of human security can be operationalized. It also supports the analysis for backing public policy decision-making in these regions that are traditionally marginalized from the institutional sphere. Having an index is also important because it would allow identifying the security dimensions with the greatest threat at any given moment.

The indices allow monitoring, evaluating, and analyzing the effects on security in any population; making comparative analyses among zones that have been affected by conflict dynamics and becoming an input for other research where the relationship between these security conditions and different socioeconomic results is analyzed. It is hoped that the results in this work contribute to broadening the debate about HS applied in specific contexts, as is the case of small areas affected by armed conflict. The development of an HSI would help improve the assessment of people's vulnerabilities and establish priorities to counteract insecurity. Even when the proposed approach was developed thinking in small and vulnerable localities, it is possible to use the same to measure the Human Security in any city or country when the perception about the security can be considered in addition to the official statistics and institutional information.

If a scale that takes values in the interval (0-100) is considered, it is possible to think that the obtained values after computing the HSI for Miranda in both cases could express a moderate level of human security perceived by the inhabitants (the moderate level was established with the help of the HS researches). This result can be explained from different perspectives. One can be that during the period of the study, the Colombian government was conducting peace talks with the FARC, the country's leading guerrilla group. For that reason, maybe the violent activities against the civilian population by the guerrillas and the state forces had decreased. However, other violent actors such as common crime and paramilitaries remained. Another possible explication would be that the people who live for many years in areas under armed conflict develop a certain degree of resilience that allows them to build strategies to live in those conditions and naturalize the problem.

6. Conclusions

The developed method uses a survey to obtain data in the field. The considered items in the instrument can be changed according to specific characteristics and necessities of the place where the HS must be measured. Some of the items used in our instrument are general and can be applied in other regions. The equations to compute the indices are very flexible and allow multiplying the coefficient (item's weight) by zero when the answer to some question is no (the individual does not remember the occurrence of the event or it did not occur).

If a random sample can be obtained, it is unnecessary to make the estimation and simulation stages in the construction of the index. In that case, it is essential to evaluate the needed assumptions to run the multivariate procedure used to obtain the weights (in terms of sample size for instance). Suppose the sample size is small and does not allow for running PCA, MFA, or MCA, but the sample can be assumed to be random. In that case, it is possible to make the estimation process using any method as maximum likelihood or moments and to use the estimates as parameter values to join the correlation matrix. With that information, the other stages described in the methods section must be followed.

If an index is constructed using counting or continuous variables, it is important to know that the interpretation of this type of indices is more straightforward if standardized values in the scale 0-100 are used. The value of the index can be or not be helpful depending on the knowledge that researchers or decision-makers have about the locality where the measures were made. To correctly interpret the value obtained for the HSI, it is necessary to know the contextual, social, and economic conditions in the study area to operationalize the actual number into categories (ordinal scale), facilitating the interpretation and analyses. The work is more straightforward with binary variables because the method returns the index value directly in a standardized form. However, as in the previous case, it is recommended to be operationalized as categorical to facilitate its use. Using the standardized scale allows to make comparative studies between geographical areas with similar characteristics in the same period or, to compare the HS performance in the same location for different periods.

The obtained data of the HSI in the Miranda municipality were used in a study carried out by the same authors of this article to compare two strategies employed to overcome the armed conflict: a counterinsurgency policy implemented in the period 2010 – 2013 in different small municipalities being, one of them Miranda and; the peace agreement between the government and the FARC the main guerrilla group in the country. Using both indices, the HS was measured before and after each strategy implementation, and the results are compared and discussed [11].

According to the literature reviewed, other indices to measure HS or any other characteristic of interest for the social and human sciences using similar methodologies were not found. For that reason, we assumed the proposed approach presents novelty in these areas of knowledge. In other contexts, two of the authors who are statisticians have worked in constructing indices under the latent variable framework using frequentist and Bayesian methods. For instance, an index to measure the pleasure of independent reading was built to be used with university students [30]. In that work, the authors using the cluster analysis with the K-means approach, propose a strategy to establish cut-points among the actual values of the index. Such values are used to create categories to define the expression levels of the latent variable measure. That approach could be considered in the case of the HS, but HS specialists must endorse the identified categories.

7. Limitations

Although the collection of information for this research was done through fieldwork with the support of some of the municipality's inhabitants, there are many cases where it is not possible to do it. Therefore, alternatives must be evaluated to access information provided by the inhabitants of this type of zone, considering that it is an excellent contribution to measure security.

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References and Notes

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Appendix

Table A1. Amounts of imputed missing data in the data file obtained after applying a survey in 55 Miranda's inhabitants.

Violent event	Memory of occurrences		Number of occurrences	
	Missing data	**%**	**Missing data**	**%**
Harassment or seizure of power by the guerrilla	2	3,6%	6	11%
Injured by landmines	3	5,5%	1	2%
Attacks with explosives	2	3,6%	6	11%
Homicides	3	5,5%	6	11%
Personal injuries or wounded by conflicts or disputes	3	5,5%	7	13%
Forced displacement	3	5,5%	7	13%
Abduction	3	5,5%	4	7%
Extortion	3	5,5%	8	15%
Forced disappearance	3	5,5%	5	9%
Torture	4	7,3%	1	2%
Unlawful detention	3	5,5%	3	5%
Threats	3	5,5%	5	9%
Terrorism	6	10,9%	2	4%
Conflicts in populated zones	2	3,6%	8	15%
Illegal checkpoints	3	5,5%	5	9%
Theft	4	7,3%	9	16%
Cattle rustling	5	9,1%	4	7%
Crop theft	7	12,7%	1	2%
Total	62	6,3%	88	9%

Table A2. Hyperparameters and parameters of Gamma prior and posterior distributions considered in the estimation process for expected amounts of violent events in Miranda's municipality during the period 2010-2013.

Violent event	Prior hyperparameter		Posterior parameter	
	alfa	**beta**	**alfa**	**beta**
Harassment or seizure of power by the guerrilla	3	1,33	120	40,3
Injured by landmines	11,5	0,35	52,5	21,3
Attacks with explosives	2	2,00	85	37,0
Homicides	48,5	0,08	247,5	42,1
Personal injuries or wounded by conflicts or disputes	60	0,07	204	35,1
Forced displacement	1825	0,00	1932	31,0
Abduction	0,5	8,00	28,5	24,0
Extortion	2	2,00	277	32,0
Forced disappearance	7,5	0,53	71,5	16,5
Torture	0,5	0.001	15,5	4,0
Unlawful detention	0,5	0.001	92,5	14,0
Threats	109,5	0,04	286,5	23,0
Terrorism	6	0,67	111	23,7
Conflicts in populated zones	11	0,36	98	31,4
Illegal checkpoints	0,5	0.001	95,5	19,0
Theft	146	0,03	782	40,0
Cattle rustling	0,5	8,00	128,5	25,0
Crop theft	0,5	0.001	0,5	5,001

Table A3. Hyperparameters and parameters of Beta prior and posterior distributions considered in the estimation process for the proportions of violent events remembered by Miranda's inhabitants during the period 2010-2013.

Violent event	Hyperparameter		Posterior parameter	
	alfa	beta	alfa	beta
Harassment or seizure of power by the guerrilla	1	1	39	15
Injured by landmines	1	1	22	31
Attacks with explosives	1	1	36	18
Homicides	1	1	43	10
Personal injuries or wounded by conflicts or disputes	1	1	36	17
Forced displacement	1	1	31	22
Abduction	1	1	17	36
Extortion	1	1	30	23
Forced disappearance	1	1	16	37
Unlawful detention	1	1	15	38
Threats	1	1	24	29
Terrorism	1	1	24	26
Conflicts in populated zones	1	1	31	23
Illegal checkpoints	1	1	20	23
Theft	1	1	41	11
Cattle rustling	1	1	17	34

Survey used to obtain data in field

QUESTIONNAIRE - PROPOSAL FOR THE CONSTRUCTION OF A HUMAN SECURITY INDICATOR FOR MIRANDA PONTIFICIA UNIVERSIDAD JAVERIANA – CALI UNIVERSIDAD DEL VALLE

Volunter No: ___

Interview date: Day : |_|_| Month |_|_| Year |_|_||_|_|

Sociodemographic data

1. Date of birth: Day : |_|_| Month |_|_| Year |_|_||_|_|
2. Sex: 1. Male __ 2. Female __
3. Educational level: 1. None __ 2.Primary __ 3. Secondary __ 4. Technical __ 5. Superior __
4. Area of residence: 1. Mountain rural __ 2. Flat rural __ 3. Urban __
5. Name of village or neighborhood: __________
6. How long have you lived in this area? 1. Years __ 2. Months __ 3. Weeks __

Experience in the armed conflict

7. During the last seven years, do you remember cases of people who have been victims of armed conflict or common crime in the area where you live?

1. Yes __ 2. No __

8. Have you or your family been affected by the armed conflict or common crime?

1. Yes __ 2. No __

9. What were the main violent events you remember that occurred in 2010-2013?

Violent event			9.1 Frequency with which the event occurred			9.2 Enter as many facts as you remember	9.3 Identify on a scale of 1 to 5, where 5 responsibility indicates greater and 1 less responsibility, the main actors that caused the violent act					
	Yes	No	Infrequent (1 to 2 times)	Frequent (3 to 5 times)	Very Common (more than 5 times)		Guerilla	Common crime	Drug traffickers	Army	Paramilitaries	New actors
1. Guerrilla harassment/takeovers												
2. Injured by antipersonnel mines												
3. Explosive Device Attacks												
4. Homicides												
5. Personal injuries or injuries due to conflict, or fights												
6. Forced displacement												
7. Kidnapping												
8. Extortion												
9. Enforced disappearance												
10. Torture												
11. Illegal retention (temporal)												
12. Threats												
13. Terrorism												
14. Clashes in a populated area with civilians involved												
15. Illegal checkpoints												
16. Thefts												
17. Animal rustling or theft												
18. Crop theft												
19. Other:_____												

10. How do you consider the security conditions in Miranda (neighborhood, urban area, or rural area) between 2010 and 2013 regarding armed conflict? (Mark with an X)

Zone	Very secure	Secure	Unsecure	Very unsecure
Neighborhood				
Urban zone				
Rural zone				

11. How do you consider the security conditions in Miranda (neighborhood, urban area, or rural area) between 2010 and 2013 regarding common crime? (Mark with an X)

Zone	Very secure	Secure	Unsecure	Very unsecure
Neighborhood				
Urban zone				
Rural zone				

12. How do you consider the security conditions in Miranda (neighborhood, urban area, or rural area) between 2014 and 2017 regarding armed conflict? (Mark with an X)

Zone	Very secure	Secure	Unsecure	Very unsecure
Neighborhood				
Urban zone				
Rural zone				

13. How do you consider the security conditions in Miranda (neighborhood, urban area, or rural area) between 2014 and 2017 regarding common crime? (Mark with an X)

Zone	Very secure	Secure	Unsecure	Very unsecure
Neighborhood				
Urban zone				
Rural zone				

14. Think about the situation in the area where you live in the period 2010-2013; if you compare the security conditions with those of the period 2014-2017, you could say that are they better, the same, or worse than they were in the years 2010-2013? (If the answer is the same, go to question number 17, otherwise, go to question number 16)

1. Better __ 2. Same __ 3. Worse __

Why?

If you select the “Better” option	Mark the reason with an X
1. Decrease in confrontations and harassment	
2. Demining	
3. Increased state presence	
4. Other: _____	

In case of selecting the “Worse” option	Mark the reason with an X
5. Greater presence of agents that generate violence	
6. More violent deaths	
7. Other: _____	

16. Do you consider that you are vulnerable to any violent act?
1. Yes __ 2. No __

17. At this moment, do you feel at risk of suffering a violent event due to the following actors? (Mark with an X)

Agent	**Yes**	**No**
1. Guerrilla		
2. Common crime		
3. Drug trafficking		
4. Army		
5. Paramilitares		
6. New emergent actors (ELN, EPL, New dissidents from the FARC guerrilla)		