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Application of Principal Component Analysis as a Technique to Obtain a Social Vulnerability Index for the Design of Public Policies in Mexico

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Abstract

The phenomenon of social vulnerability is understood as the set of limitations or disadvantages to access a quality life. This work aims to obtain a Social Vulnerability Index at the municipal level in Mexico, using the principal component analysis technique (Yengle, 2012; Ruano, 2015; Olivares, 2014; Borja-Vega & de la Fuente, 2013; Rueda-Torres & Gonzalez-Longatt, 2018), 12 indicators were calculated, organized into three categories: sociodemographic, socioeconomic and habitat, typical of each territorial space in Mexico, to know the factors that determine social disadvantages in the population. The results show that food poverty, heritage poverty and educational backwardness are the main factors that affect social vulnerability, which highlight the need to design specific public policies, through a process of articulation and coherence with the different social actors, in order to contribute to closing subnational social gaps and developing the endogenous capacities of the territories so that they have an impact on the social development of the country.

Keywords

Main Components, Index, Social Vulnerability, Public Policies

1. Introduction and Context

Based on the work of various authors who have contributed to the field of study of social vulnerability in the last two decades, in Latin America Kaztman (1999), Rodríguez-Vignoli (2000), Fligueira (2001), Busso (2002) and Moreno-Crossley (2008); in other continents, Graham (2002), Ligon & Schechter (2003), Chaud-

huri, Jalan, & Suryahadi (2002), Barrientos (2010), Arora-Jonsson (2011), social vulnerability is recognized as an object of study that must be addressed from an analytical and methodological perspective of social welfare, whose empirical data and theoretical approaches should be useful in the construction of regionalized policies that contribute to the social development of national and sub-national territories.

In Mexico, 52.4 million people live in poverty, a figure that is equivalent to 41.9% of the population and that represents a decrease of just 2.5% compared to the percentage registered in 2008 when the percentage was 44.4%. Of extreme poverty they amount to 9.3 million, equivalent to 7.4% of the population; the vulnerable population due to income corresponds to 8.6 million people, and due to social deprivation, 36.7 million people. The non-poor and non-vulnerable population in the entire country is 24.7 million people, according to figures from the National Council for the Evaluation of Social Development Policy (CONEVAL, for its acronym in Spanish) (2018).

This situation frames structural imbalances of all kinds: economic, social, political, cultural and environmental aspects, which in the end make the conjunction of the term social vulnerability more representative in its analytical dimension, that is, the incapacity of population groups with weak foundations that They may face circumstances of poverty, precarious wages, lack of basic urban services, access to public health and low educational level.

Vulnerability is also related to factors such as population growth and the proliferation of settlements to live in high-risk places, industrial intensification, deterioration and the lack of infrastructure or territorial equipment; as well as by the local effects accumulated by the processes of environmental deterioration (SEMARNAP, 2000; Tudela, 2004; Carabias et al., 2005). As Sojo (2004) points out, it is essential to configure programs that address the heterogeneity of poverty through selective policies, since the wide range of vulnerability constitutes a severe wake-up call regarding the quality and sustainability of economic development.

Based on the previous proposals, from the approach of applying a factor analysis, the principal component analysis technique (PCA) is used to discuss the main factors involved in social vulnerability, which influence the reproduction of unfavorable conditions of the population, synthesized in an exploratory index of social vulnerability (SVI) applied to political jurisdiction municipalities of Mexico, to identify some edges that allow to outline public policies focused on problems that produce social disadvantages.

The development of perspectives and methodological approaches developed over the last two decades, allows compiling some related dimensions in the study of social vulnerability, however, given the complexity of the phenomenon, it is recognized that there are multiple immersive aspects that must be explored. Therefore, only twelve variables that are considered relevant in the Mexican context are included in the analysis. The theoretical-methodological axes that have been estimated are those related to the sociodemographic, socioeconomic

and habitat dimensions.

The main sources of the available indicators are the National Institute of Statistics and Geography (INEGI, for its acronym in Spanish), National Population Council (CONAPO, for its acronym in Spanish), National Council for the Evaluation of Social Development Policy (CONEVAL, for its acronym in Spanish). The base data are obtained from the general census, which is carried out with a periodicity of 10 years and which should have been carried out in the current year 2020, which due to the emergence of the disease by COVID-19, was not carried out in a way complete, so the 2010 data was used, due to the requirements of the mathematical model (see Table 1).

In the sociodemographic dimension, the indicators of the overcrowding index, demographic dependency rate and percentage of population in localities with less than 2500 inhabitants (rural population) are considered. The socioeconomic dimension includes indicators related to the percentage of the population in food poverty, the percentage of the population without the right to health services, the percentage of the population from 6 to 14 years of age who does not attend school and the percentage of the population of 15 years of age and more

Table 1. Theoretical-methodological structure: dimensions, variables and indicators of the exploratory index of social vulnerability.

Dimensions of social vulnerability	Variables	Available indicators	Sources
Sociodemographic	Overcrowding	Index of overcrowding	CONAPO
	Demographic dependency	Demographic dependency rate	INEGI
	Rurality	Percentage of population in localities with less than 2500 inhabitants	INEGI
Social protection	Health	Percentage of the population without access to health services	INEGI
Education and knowledge	Education	Percentage of the population aged 6 to 14 that does not attend school	INEGI
		Percentage of the population aged 15 years and over with incomplete basic education	INEGI
Income	Social deficiencies	Percentage of population in food poverty	CONEVAL
Housing and habitat	Water	Percentage of inhabited private dwellings that do not have water	INEGI
	Sewer system	Percentage of inhabited private homes that do not have sewer system	INEGI
	Quality in housing	Percentage of private dwellings inhabited with dirt floors	INEGI
Patrimonial Capital	Durable goods	Percentage of inhabited private homes that do not have a refrigerator	INEGI
		Percentage of inhabited private homes that do not have a washing machine	INEGI

Source: self-made.

with incomplete basic education. And, in the dimension of habitat, the indicators of percentage of inhabited houses that do not have piped water, drainage, refrigerator and washing machine were considered, in turn, the percentage of inhabited houses with a dirt floor.

2. Materials and Method

2.1. Calculation of the Indicators

Overcrowding index

The overcrowding index measures the degree of agglomeration of people per bedroom, where the reduced space and/or surface area are insufficient to accommodate all individuals comfortably and safely. In this way, a home has some level of overcrowding if the following condition is met:

(Number of occupants)/(Number of bedrooms) > 2

$$I_{i1} = \frac{V_i^h}{V_i^t - NE_i^n} * 100 \quad (1)$$

Explained as:

V_i^h = Private houses inhabited with some level of overcrowding;

V_i^t = Total of municipal inhabited private dwellings;

NE_i^n = Inhabited private dwellings for which the number of bedroom rooms was not specified.

Demographic dependency rate

The form of the calculation is based on a strictly biological criterion, establishing that all people between 15 and 65 years are active potentials (without distinction), while the population outside this age range is considered potentially inactive or dependent. The following formula was applied to calculate the demographic dependency rate:

$$I_{i2} = \frac{P_i^n + P_i^a}{P_i^{act} - NE_i^{ed}} \quad (2)$$

Explained as:

P_i^n = Population from 0 to 14 years old;

P_i^a = Population aged 65 years and over;

P_i^{act} = Population between 15 and 64 years of age;

NE_i^{ed} = Population that did not specify their age.

Rural population

The National Institute of Statistics and Geography (INEGI, for its acronym in Spanish, 2010) defines rural towns as those with up to 2500 inhabitants, towns above this number are considered urban. The calculation of this indicator is described as follows:

$$I_{i3} = \frac{P_i^{rur}}{P_i^t - NE_i^{lo}} * 100 \quad (3)$$

Explained as:

P_i^{rur} = Population in localities with 2500 inhabitants or less;

P_i^t = Total municipal population;

NE_i^{lo} = Population that did not specify the locality.

Food poverty

Food poverty is measured by the food basket, which represents the set of foods whose value serves to build the minimum welfare line, these are determined according to the consumption pattern of a group of people who satisfy their needs with them, such as energy and nutrient requirements. Food poverty is understood as the inability to obtain such a basket, even if all the disposable incomes in the household were used to buy only the goods in said basket. The indicator of food poverty is provided by the National Council for the Evaluation of Social Development Policy (CONEVAL, for its acronym in Spanish) through its open data, which obey the following formula:

$$I_{i4} = \frac{P_i^{sca}}{P_i^t - NE_i^{ca}} * 100 \tag{4}$$

Explained as:

P_i^{sca} = Population that does not cover a basic food basket with their income;

P_i^t = Total population;

NE_i^{ca} = Population that did not specify the income to access a basic food basket.

Population without rights to health services

The information on the population without the right to health services was provided from the (INEGI, for its acronym in Spanish, 2010). In order to know the percentage of the population without the right to health services, the following formula was followed. The calculation results from the population division that specifies that it does not have the right to health services among the total political jurisdiction municipality population, minus the population that did not specify their condition as health services:

$$I_{i5} = \frac{P_i^{sd}}{P_i^t - NE_i^s} * 100 \tag{5}$$

Explained as:

P_i^{sd} = Population with no right to health services;

P_i^t = Total population;

NE_i^s = Population that did not specify their condition of entitlement to health services.

Population from 6 *to* 14 *years old that does not attend school*

Similar to the previous indicator, statistical information is found in (INEGI, for its acronym in Spanish, 2010). The percentage of the population of children and youth who does not attend school is calculated by dividing the population of 6 to 14 years who do not attend school by the total population of the same age, minus the population that did not specify their condition of school attendance, multiplied by 100. The formula is described as follows:

$$I_{i6} = \frac{P_i^{na}}{P_i^{nm} - NE_i^a} * 100 \quad (6)$$

Explained as:

P_i^{na} = Population from 6 to 14 years of age that does not attend school;

P_i^{nm} = Population from 6 to 14 years old;

NE_i^a = Population from 6 to 14 years of age who did not specify their condition of attending school.

Population over 15 *years of age with incomplete basic education*

Statistical information was tracked through (INEGI, for its acronym in Spanish, 2010). To know the percentage of the population over 15 years of age with incomplete basic education, the following formula is followed:

$$I_{i7} = \frac{P_i^{si} + P_i^{cp} + P_i^{tp} + P_i^{apr}}{P_i^q - \left(NE_i^{sec} + NE_i^{inst}\right)} * 100 \quad (7)$$

Explained as:

P_i^{si} = Population of 15 years or more without instruction, considering those who attended preschool;

P_i^{cp} = Population of 15 years or older that passed at least one year in primary school;

P_i^{tp} = Population of 15 years or more with technical or commercial studies with finished primary;

P_i^{tp} = Population aged 15 and over who passed between the first second year of high school;

P_i^q = Population aged 15 or over;

NE_i^{sec} = Population aged 15 years and over who did not specify their passing grade in secondary school;

NE_i^{inst} = Population aged 15 years and over who did not specify their level of education.

Private inhabited homes that do not have piped water

Through the statistical consultation of open data from (INEGI, for its acronym in Spanish, 2010), the information for the development of this indicator was obtained. According to the methodology followed by INEGI, the formula to describe the percentage of private inhabited homes that do not have piped water is represented as follows:

$$I_{i8} = \frac{V_i^{af} + V_i^{sa}}{V_i^t + NE_i^a} * 100 \quad (8)$$

Explained as:

V_i^{af} = Inhabited private dwellings that have piped water outside the dwelling but within the land;

V_i^{sa} = Inhabited private dwellings that have access to clean water from a communal water source or hydrant;

V_i^{sa} = Total of private inhabited dwellings;

NE_i^a = Inhabited private dwellings for which water availability was not spe-

cified.

Private inhabited homes that do not have drainage

Similar to the previous query, the collection of statistical information was found in the INEGI open data. According to the INEGI methodology, the formula for calculating the percentage of inhabited private homes that do not have drainage is described as follows:

$$I_{i9} = \frac{V_i^d + V_i^{drlm} + V_i^{sd}}{V_i^t + NE_i^d} * 100 \quad (9)$$

Explained as:

V_i^d = Private houses with drainage connected to a ravine or crevice;

V_i^{drlm} = Private houses inhabited with drainage connected to the river, lake or sea;

V_i^{sd} = Total of inhabited private dwellings without drainage availability;

V_i^t = Total of private inhabited dwellings;

V_i^t = Inhabited private dwellings for which the availability of drainage was not specified.

Private houses inhabited with a dirt floor

Statistics are provided by (INEGI, for its acronym in Spanish, 2010). Through open data. According to the INEGI methodology, the formula for calculating private dwellings inhabited with a dirt floor obeys the following formula:

$$I_{i10} = \frac{V_i^{pt}}{V_i^t - NE_i^p} * 100 \quad (10)$$

Explained as:

V_i^{pt} = Total of private dwellings inhabited with dirt floor;

V_i^t = Total inhabited private dwellings;

NE_i^p = Inhabited private dwellings for which the type of floor was not specified.

Inhabited private homes that do not have a refrigerator

The statistics are provided by (INEGI, for its acronym in Spanish, 2010). through open data. According to the INEGI methodology, the formula for calculating inhabited private homes that do not have a refrigerator obeys the following formula:

$$I_{i11} = \frac{V_i^{sr}}{V_i^t - NE_i^{dr}} * 100 \quad (11)$$

Explained as:

V_i^{sr} = Inhabited private dwellings that do not have a refrigerator;

V_i^t = Total of private inhabited dwellings;

NE_i^{dr} = Inhabited private dwellings for which the availability of a refrigerator was not specified.

Private inhabited homes that do not have a washing machine

Similar to the previous indicator, statistical information was tracked by INEGI's open data. The formula for this indicator is described as follows:

$$I_{i12} = \frac{V_i^{sl}}{V_i^t - NE_i^{dl}} * 100 \tag{12}$$

Explained as:

V_i^{sl} = Inhabited private dwellings that do not have a washing machine;

V_i^t = Total of inhabited private dwellings;

NE_i^{dl} = Inhabited private dwellings for which the availability of a washing machine was not specified.

2.2. Principal Component Analysis (PCA)

The PCA technique aims to explain most of the total observed variability of the set of variables with the fewest number of components possible, transforming the set of original variables that are correlated with each other into another set of uncorrelated variables, called factors or main components, related to the first ones through a linear transformation, and that are ordered according to the percentage of total variability that they explain. It is chosen from among the main components that explain the greatest accumulated variability, thus reducing the total size of the information set (Schuschny & Humberto, 2009: p. 42).

The principal components construction technique ensures that the first principal component is the one that explains a higher percentage of variance of the data. The 12 indicators that make up the social vulnerability index (SVI) have already been described above. The matrix of the SVI is expressed as follows:

$$X = \begin{bmatrix} I_{1.1} & I_{1.2} & \cdots & I_{1.12} \\ I_{2.1} & I_{2.2} & \cdots & I_{2.12} \\ \vdots & \vdots & & \vdots \\ I_{i.1} & I_{i.2} & \cdots & I_{i.12} \end{bmatrix} \tag{13}$$

where the first subscript is the state and the second subscript is the indicator. Subsequently, a standardization of the values of the 12 indicators of each analysis unit will be carried out, obeying the following formula:

$$Z_{ij} = \frac{I_{ij} - \overline{I}_j}{ds_j} \tag{14}$$

Explained as:

Z_{ij} = Standardized indicator j of the observation unit i;

I_{ij} = Indicator j of the observation unit i;

$\overline{I}_j$ = Arithmetic average of the values of indicator j;

ds_j = Unbiased standard deviation of indicator j;

i = Subscript indicated by the observation unit i ($i = 1, \cdots, 2456$ municipalities);

j = Subscript indicated by the standardized indicator j ($j = 1, \cdots, 12$ indicators that make up the social vulnerability index).

Each variable has important properties for its management and interpretation (all standardized variables have mean 0 and variance 1), in this way all the study variables have the same mean and standard deviation, none weighs more than

the other. Each standardized indicator j has the following properties:

$$prom\left(Z_{ij}\right)=\bar{Z}_{ij}=\frac{1}{n}\sum_{i=1}^{n}Z_{ij}=0 \tag{15}$$

$$var\left(Z_{ij}\right)=V_{ij}=\frac{1}{n}\sum_{i=1}^{n}\left(Z_{ij}-\bar{Z}_{j}\right)^{2}=1 \tag{16}$$

$$desv\left(Z_{ij}\right)=\sqrt{\frac{1}{n}}\sum_{i=1}^{n}\left(Z_{y}-\bar{Z}_{j}\right)^{2}=1 \tag{17}$$

After the standardization of the units of analysis, a new matrix appears, where the Z values are the standardized values of the indicators. The matrix is expressed in the following way:

$$Z=\begin{bmatrix} Z_{1.1} & Z_{1.2} & \cdots & Z_{1.12} \\ Z_{2.1} & Z_{2.2} & \cdots & Z_{2.12} \\ \vdots & \vdots & & \vdots \\ Z_{2456.1} & Z_{2456.2} & \cdots & Z_{2456.12} \end{bmatrix} \tag{18}$$

Principal component analysis (PCA) transforms the space of the Z vectors into a new one, in which is a Y_k ($k=1,\cdots,12$), that is, the new set calculated as the linear combination of the Z vectors and the transformation coefficients or weights. This new set is known as main components. And it is expressed in the following way:

$$\begin{aligned} Y_1 &= \omega_{1.1}Z_1+\omega_{1.2}Z_2+\cdots+\omega_{1.12}Z_{12} \\ Y_2 &= \omega_{2.1}Z_1+\omega_{2.2}Z_2+\cdots+\omega_{2.12}Z_{12} \\ &\vdots \\ Y_{12} &= \omega_{12.1}Z_1+\omega_{12.2}Z_2+\cdots+\omega_{12.12}Z_{12} \end{aligned} \tag{19}$$

In each analysis unit, the 12 hierarchical components can be constructed, according to the results of the correlation matrix. Each new component is generated by the standardized values, the difference between them is the quantity ω_{ik} used, ω_{ik} express a vector k with weights for each indicator. The principal component analysis allows the weights or weights to be obtained from the analysis of the correlation matrix V of the standardized indicators: $\omega_{1k},\omega_{2k},\omega_{3k},\cdots,\omega_{12k}$, which multiply to the standardized values to obtain the component K. This set of values placed in column mode they make vector $\underline{\omega}$; its importance lies in being a special vector or eigenvector of the matrix V^{20}. For a matrix of correlations of size 12, there are 12 eigenvectors and the condition they meet is expressed as follows:

$$V\underline{\omega}=\lambda\underline{\omega} \tag{20}$$

The correlation matrix has 12 vectors ω and 12 eigenvalues λ that as a pair are mutually determined, each value λ is a positive eigenvalue. The eigenvalues of the matrix are numbered according to their magnitude, such that:

$$\lambda_1\geq\lambda_2\geq\lambda_3\geq\lambda_4\geq\lambda_5\geq\lambda_6\geq\lambda_7\geq\lambda_8\geq\lambda_9\geq\lambda_{10}\geq\lambda_{11}\geq\lambda_{12}>0 \tag{21}$$

Furthermore, it can be pointed out that the total variance of the matrix V is equal to what is called the trace of the matrix V $n\times n$ which is defined as the

sum of the elements of the main diagonal of V, and also, that the eigenvalues determine the importance of the variances in each component. The trace is then the total variance, so two situations are met:

- $Traza(V) = \sum_{j=1}^{12} V_{jj} = 12$ (22)
- $\sum_{j=1}^{12} \lambda_j = 12$ (23)

In this way, the relevance of each component is considered according to the proportion of variance that explains the total of the 12 eigenvectors. And to know its relative importance it is enough to divide the eigenvalue by 12:

$$Importance_j = \frac{\lambda_j}{12} \quad (24)$$

Therefore, to construct the municipal-level social vulnerability index (SVI), the first eigenvector is used together with its eigenvalue. For the principal component technique, these matrix properties represent static results: the eigenvector will determine a direction for the standardized values and the eigenvalue, a relevance of the variance of the index. The new value:

$$Y_1 = \omega_{1.1} Z_1 + \omega_{1.2} Z_2 + \cdots + \omega_{1.12} Z_{12} = \underline{\omega}_1 \underline{Z}_1 \quad (25)$$

In this way, the IVMS takes the qualification of summary measure, due to the fact that it modifies the 12 original standardized variables, and summarizes their effect in their single value:

$$Y_1 = \underline{\omega}_1' \underline{Z} = IVS \quad (26)$$

From the above, it can be summarized then that the SVI calculated as the first component of the PCA, allows us to affirm that it is the linear combination that best summarizes in a single value the information provided by the set of 12 indicators; it also recovers both the multidimensional character and the variation structure of the indicators and makes it possible to order each unit of analysis from the index after the construction of the indicator.

3. Results of the Social Vulnerability Index (SVI)

The choice of the PCA technique as an estimation technique lies in two main aspects, the first, in that as a measure it is capable of differentiating the states of the Mexican republic according to the global impact of the social vulnerability suffered by the population; and the second, in the multidimensionality of social vulnerability as a study phenomenon, since this type of technique is usually used when the objective is to group the variables into a larger category.

Likewise, the Kaiser-Meyer-Olkin (KMO) adequacy measure is estimated, which indicates the proportion of variance that the analyzed variables have in common, which turned out to be for the indicators in 2010 of 0.886, which means that the PCA is not only desirable, but also a good fit to the structure of the data. The Bartlett sphericity test was also considered, which makes it possible to ensure that if the critical level is greater than 0.05, it is possible to accept the null hypothesis of sphericity (that there is an identity matrix). In this way, it was

possible to verify that for 2010 a statistical significance value of 0.001 was obtained, so that the null hypothesis can be rejected, and thus consider the adjustment of the variables to be appropriate through factor analysis (see Table 2).

After carrying out the previous tests, the eigenvalues of the correlation matrix and the explained variance of each of the components at the municipal level for 2010 are obtained. Now, when projecting the space defined by the 12 indicators on a smaller one dimension, and according to the Kaiser-Meyer Olkin criterion that indicates that the main components whose eigenvalues are greater than unity must be conserved, it can be seen in Table 3 that eigenvalue starts from component number two to be much lower than the previous one.

This allows only the first component to be taken to calculate the exploratory social vulnerability index (SVI). Thus, the linear correlation levels existing between most of the variables lead to the total variation explained by the first main component for 2010 being 54.1%.

Once the components have been estimated and after verifying that the use of the principal components technique is pertinent, the coefficients of the first principal component (ω) that will weigh each of the standardized indicators can be defined, and obtain the first principal component, is that is, the SVI at the municipal level for 2010, as a linear combination of the indicators. Table 4

Table 2. KMO and Bartlett test.

Kaiser-Meyer-Olkin measure of sampling adequacy		0.886
Bartlett Sphericity Test	Approx. Chi-square	23,280.472
	gl	66
	Sig.	0.0001

Source: self-made.

Table 3. Explained variance principal component analysis.

Total	Component λ	Variance Percentage	Accumulated Percentage
1	6.502	54.18	54.184
2	1.087	9.05	63.239
3	0.995	8.288	71.526
4	0.904	7.534	79.060
5	0.759	6.323	85.384
6	0.462	3.847	89.231
7	0.397	3.311	92.542
8	0.340	2.833	95.374
9	0.209	1.740	97.115
10	0.183	1.521	98.635
11	0.095	0.794	99.429
12	0.069	0.571	100.000

Source: self-made.

Table 4. Table type styles (Table caption is indispensable).

Indicators	First component	Weighting (ω)
Food poverty	0.941	0.145
Private inhabited homes that do not have a washing machine	0.904	0.139
Private inhabited homes that do not have a refrigerator	0.894	0.137
Population aged 15 and over with incomplete basic education	0.827	0.127
Dependency rate	0.794	0.122
Private inhabited homes that do not have drainage	0.767	0.118
Overcrowding index	0.754	0.116
Private houses inhabited with a dirt floor	0.741	0.114
Rural population	0.603	0.093
Private inhabited homes that do not have piped water	0.562	0.086
Population from 6 to 14 years old that does not attend school	0.420	0.065
Population without health services	0.353	0.054

Source: self-made.

shows the coefficients of the main component, which serve as the basis for calculating the social vulnerability index, as well as the respective weight for each variable.

The component score coefficient matrix reflects the variables with the greatest weight within the municipal Social Vulnerability Index (SVI), where food poverty is first (0.941); followed by the lack of material assets in the home of (without washing machine—0.904—and without refrigerator—0.894) and the population older than 15 years with incomplete basic education (0.827).

The results show that the conditions linked to these variables are added as the main determinants of the disadvantages and social vulnerability of the different municipalities of Mexico. Poverty is represented in its maximum expression when people do not access a basic food basket, even though they use all their income for it, added to the lack of durable goods in the home contributes to a discouraging scenario for people and households in Mexico. In turn, incomplete basic education is added as another determinant. The educational level influences obtaining upward social mobility, it is linked to the labor market and the possibilities of insertion of people with better incomes.

Investment in education provides the necessary knowledge for the technological, cultural, ethical, political, productive, and economic development, among others, that is associated with better life opportunities for the population. Finally, once the SVI value for each municipality has been calculated, they are classified into five groups of social vulnerability: very low, low, medium, high and very high based on the Optimal Stratification Technique, developed by Dalenius and Hodges (1957), which consists of the formation of strata so that the variance obtained is minimal for each stratum.

In this way, the spatial (territorial) distribution of social vulnerability in Mex-

ico can be seen in Figure 1. Which focuses on the areas or regions of the country that need greater intervention of national and community policy, which allows reducing vulnerability in the Mexican territory. It can be pointed out that the south-southeast, central-western and some north-western areas show signs of very high social vulnerability, where public policies regarding poverty, basic education and coverage of access to basic household materials, would allow a great advance in those regions to transit to less vulnerable environments. Table 5 shows the stratification of the data, of the 2456 municipalities in Mexico, 281 reflected very high vulnerability, 493 in high vulnerability, 610 municipalities have medium strata of vulnerability, the rest register low and very low degrees of vulnerability.

The most vulnerable municipalities in Mexico are Cochoapa el Grande (Guerrero), Chalchihuitán (Chiapas), Tehuipango (Veracruz), San Juan Petlapa (Oaxaca), Santiago Amoltepec (Oaxaca), Metlatónoc (Guerrero), San Juan Cancuc (Chiapas), Mixtla de Altamirano (Veracruz), Coicoyán de las Flores (Oaxaca), Santa Lucía Miahuatlán (Oaxaca), amongothers. The states that also showed the

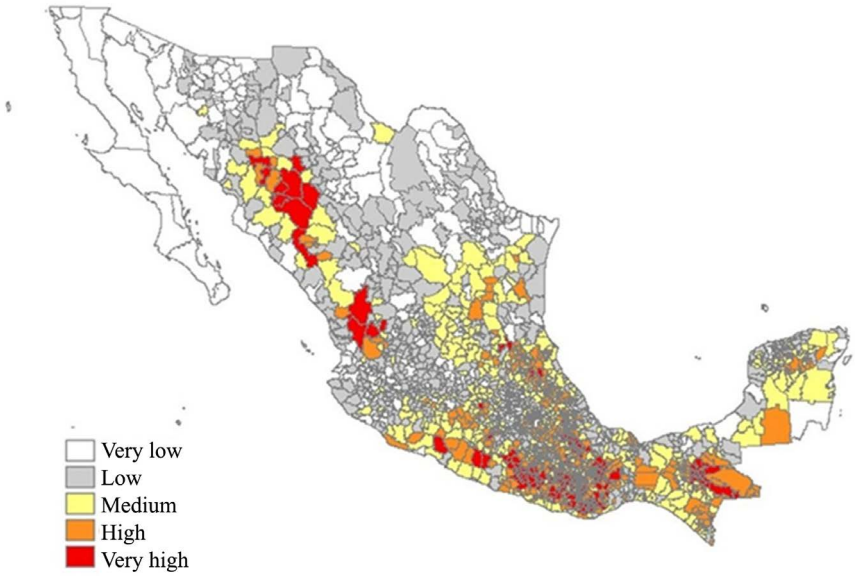

Figure 1. Map about social vulnerability in Mexico. Source: self-made.

Table 5. Stratification of the data. Vulnerability of municipalities.

Strata of social vulnerability	Value		No. Munipalities
	Minimum	Maximum	
Very low vulnerability	−2.2292	−0.9950	413
Low vulnerability	−0.9950	−0.3175	659
Medium vulnerability	−0.3175	0.4646	610
High vulnerability	0.4646	1.3639	493
Very high vulnerability	1.3639	3.3934	281

Source: self-made.

highest incidence in this category are Puebla, Chihuahua y Durango. Some municipalities with medium vulnerability of interest are Reyes de Juárez (Puebla), San Sebastián Abasolo (Oaxaca), Tuzamapan de Galeana (Puebla), San Juan Atzompa (Puebla), General Felipe Ángeles (Puebla), San Francisco Chindúa (Oaxaca), Espita (Yucatán), Lolotla (Hidalgo), San Miguel Amatlán (Oaxaca) y Agua Blanca de Iturbide (Hidalgo), since they represent a high probability of incurring in high social vulnerability schemes.

4. Final Thoughts

In the context of the results presented in the work, it becomes essential to determine more accurate public policies that contribute to reducing the macroeconomic impacts on the living conditions of households, for this, new analytical and methodological frameworks are required to measure the complex social phenomena and their constant changes.

Territorial disparities in Mexico have structural roots and can be observed in institutional forms that reproduce exclusion of rights and concrete situations of material deprivation and intergenerational transmission of poverty in homes and communities.

From the interpretative code of the social vulnerability approach, territorial development at a subnational scale requires strengthening endogenous capacities with an emphasis on prevention, adaptation and resilience capacities, focused on the endowment and diversification of the resources that citizens, families and communities possess. such as: basic education, durable goods at home, decent work, access to health services, quality of housing and efficient public services, particularly in the territories with the greatest socioeconomic disadvantage.

The construction of an exploratory indicator of social vulnerability in Mexico turns out to be a useful measure for public policies, in the first instance, to know which are the main determinants of social disadvantage in sub-national territories, and in the second to identify the areas with the greatest disadvantage and priorities of attention.

Having clarity about the main components of social vulnerability allows the formulation of specific public policies. The most visible and concrete variable lies in food poverty, (which scores 0.941 in the valuation matrix), and its solution is directly related to income, this with employment and the productive capacities of people. The lack of productive capacities can be deduced from the existence of precarious jobs, for which a public policy of intervention consists of specific training programs for work and of consultation with employers so that the resulting increase in productive capacity impacts the income by way of salary improvement.

As it is about breaking a trans-generational vicious circle, a package of public policies that guarantee children's rights to food and school attendance must be implemented at the same time (which scores 0.827 in the evaluation matrix) since it is well established Of course, the greater the number of school years, the greater the possibility of improving the employability conditions and therefore

the living conditions, (those of the population score without a washing machine—0.904—and without a refrigerator—0.894). This is an apparently simplistic outline, which will have to be converted into concrete public policy actions adapted to the social, economic, political and cultural characteristics of each municipality. Taking into consideration that the results obtained to establish that, of the 2456 municipalities in Mexico, 281 reflected very high vulnerability, 493 highly vulnerable, 610 municipalities have medium strata of vulnerability, the rest register low and very low degrees of vulnerability. In this context, the regions of the country that need the most national and community policy intervention are the south-southeast, central-west and some areas of the northwest, which show signs of very high social vulnerability, where public policies on poverty, Basic education and coverage of access to basic household materials are of great importance to move to less vulnerable environments, allowing to move towards sustainable development.

Only through effective policies, from the point of view of the social impact they generate and the efficiency in the use of resources, can the actions of the State be legitimized to improve the living conditions of its population, in the field of sustainability of development, in its social, economic and political dimension.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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