

# A methodology to assess vulnerability: Informal urban sprawl on the green belt of Mexico City

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## Abstract

*The articles present a formula developed to measure degrees of vulnerability. Assessing vulnerability is a key tool for planning and urban projects in developing countries. To address this situation, a methodology is developed from scratch using data gathered from several territorial management projects done in Mexico City. The variables used to build it are: i) construction quality of the house, ii) level of education for each inhabitant, iii) number of elders or small children in the house, house overcrowding, and iv) income levels per household. The formula uses a system of weighting to set the relevance of each variable in the formula. The used data comes from fieldwork and in situ surveying. The paper gives necessary tools to modify and use the formula in other cases and scenarios.*

**Keywords:** vulnerability; assessment; Mexico City; informal sprawl

## 1. Introduction

The present article presents a formula to assess the degree of vulnerability or lack of resilience in social groups in an urban environment and help the process of urban planning for the authorities. At the moment of design two considerations were essential; the first one, cities have been defined as specific entities with demographic, economic, environmental, social and cultural characteristics and problems unique to each city. The second one is, city authorities have well defined administrative limits that limit the reach and agency of the local governmental dependency.

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The urban conglomerate encompasses a series of interactions. In the case of Mexico City, there is a transition belt from urban to rural lands, resulting in several phenomena. These include commuting from the periphery to the work centers around a metropolitan area; exchange of goods, people and other capitals (Tacoli, 1998); unfolding of the urban sprawl into conservation lands or green belt spaces (Santos Cerquera, 2013), and even local migration processes (Aguilar, 2018). In developing economy cities, this translates into underperforming or even absent public utilities and services, such as schools, public transport, and medical infrastructure. Framing in these considerations, the need for a reliable, sensitive, and malleable to the local context methodology and accompanying formula has stemmed the following work.

## **2. The need for a formula**

### ***2.1. Historical p of urban sprawl in México City***

Like many other countries during the 20th century, Mexico suffered a drastic change through the rural migrations from rural areas to the cities, driven by the economic and production systems. In the current century, non-traditional population movements took the spotlight, for example, migration from a smaller city to a larger one, as well as the growth of rural-like self-organized developments in the periphery of the larger urban centers (Pérez-Campuzano and Santos-Cerquera, 2013). Resulting in complex processes that gave rise to new structures, patterns, and networks of interactions between actors with conflicting agendas. Therefore, cities are non-linear systems, dynamic and unstable entities (Roo, 2017). The ability to develop systems and planning tools with an adaptive capacity brings the ability to overcome deadlocks is a crucial point in the agenda of decision makers (Giezen et al., 2015) in the public managing duties.

In Mexico currently, a vast amount of scenarios with different degrees and types of socio-spatial segregation, are linked to social factors like income and education (G. Aguilar and López, 2016). As well as, spatial factors like ease of access, the likelihood of a natural disaster, and the service and infrastructure availability (L. Cutter et al., 2003). While the first factor (income and education) is a byproduct of significant social complications, the second (likelihood of a natural disaster) and third (service and infrastructure availability) are undeniable proof of the lack of capacity of the government at several levels. Examples of this inability from the authorities are the lack of a proper spatial regulation and the lack of capacity to provide the essential services and prevent unnecessary risks by allowing population in improper lands for housing. Added to the described factors, outside of the conservation lands and green belts, the dominance of an informal job market boosts the informal sprawl of the city (Pérez Campuzano and Santos Cerquera, 2011). The urban expansion in the periphery of Mexico City takes place through illegal processes, where people of all sorts of income find the chance of settle in an informal development, moved by different and sometimes contradictory reasons (Santos Cerquera et al., 2014). A typical feature of the informal settlements is a location in areas without the minimum characteristics to provide safety to the inhabitants from a natural phenomenon, leaving the door open for a major disaster to happen any given time (Instituto de Geografía, 2011).

### ***2.2. The need to quantify the vulnerability***

For many years, only after a natural disaster happened, the need to build a comprehensive scale to measure vulnerability rises. For example, the discussion that Bailey and Zenteno (2015) held about the fire that took place in Valparaiso in 2014, a central topic is how vulnerability affects the

population. In the paper, they elaborate on the conversations between Rousseau and Voltaire. The discussion is used as a pivot to explain the direct relation of, the decision on where to settle and how to build, with the occurrence of a natural phenomenon; giving the chance of a combination to result in disaster for the local populations. Moreover, they conclude how the concept of disaster links to social and economic losses, more than natural processes.

In the other hand, in some cases not even the threat of a disaster convinces people to avoid settling on areas cataloged as dangerous; such areas get population by a mix of a collection of social and economic reasons and a lack of understanding of the local geography (Santos Cerquera et al., 2014). An alarming situation appears, when the described situation mix with a complex problem of land management, where both the people in the settlement and the government are gears in a disaster to come.

### ***2.3. Measuring natural and social issues***

Constructing a scale to measure is a natural step towards better public policy (air quality (Patarasuk et al., 2016), ecosystem services (Wong et al., 2015), life quality (Tonon, 2010)). The measurement of the vulnerability for specific populations is a tool to quantify the degree of transformation in their daily life through external alterations, caused by a natural phenomenon in short spans of time, like a landslide, earthquake, or flooding. So vulnerability is understood as a conjunction of the possible situation of a natural process with the chance of affecting an individual or a specific population (Cardona, 2002).

Measuring vulnerability as a social element has gained strength in the academy and as a theoretical concept to explain the transformations produced by the social and economic changes derived from the globalization, especially on the socioeconomic status of the people in the lowest income tier (Stålsett, 2004). The economic and social gaps have been used as a guideline to measure vulnerability; nevertheless, the spatial or geographical characteristics should be included in the considerations made to fix and method or scale to measure vulnerability, to the point of considering the obtained results in the land management process

Prior attempts to develop a formula consider specific scenarios to measure specific types of vulnerability or a desired level of resilience are not allowed in Mexico City. It is stated in the applicable law, the necessity of a single scale to measure vulnerability (Santos Cerquera et al., 2014), the same scale should contain all the steps of the economic specter, including all, from low-income to high-income households. (Castro and Salinas, 2016). The approach for the presented formula is linked to the human needs directly found in the informal human settlements and the specific conditions that prevail in the larger Latin American cities (Caraveo, 2009) ( Sánchez-Vega et al., 2000) (Valdebenito, 2014). Recognizing these settlements as part of the complete urban system (Schteingart and Salaza, 2003) and giving them a frame to understand the corresponding rights and obligations of the inhabitants of such spaces.

### ***2.4. Definition of the target population***

The target population for the presented formula is settled in the developed zones product of informal urbanization processes and still hold unregulated status. The dwellers of the informal settlements are part of the urban dynamic of Mexico City. Studies done by the research group, show a social spectrum composed mainly of mid to lower income households. Including also, a

healthy amount of variety in both extremes of the economic ladder, cases of extreme poorness and copious amounts of wealth (Figure 1 (a) (b)).

The data used to build the formula comes from several land management projects done by the research group in two municipalities of Mexico City. The total amount of evaluated informal settlements adds up to 46. 21 in the Tlalpan municipality and 25 in Tláhuac municipality. Each municipality had its own project rules, the selected settlements for both projects have the common characteristic of leaning towards a complete transformation of the natural landscape towards spaces in urban spaces. Thanks to the longtime of the establishment, ranging from one to several decades. A key finding during the projects is a typical migration pattern; to the regular and lower income people first migrating from different regions of the country neighborhoods in Mexico City. Then moving again to the informal settlements located in periphery inside the green belt of the city. Going further to establish in the same municipality in both stages of the process. Another characteristic of the migration within the metropolis is how regional or family groups follow the same spatial pattern, moving along to the same neighborhoods and informal settlements. This behavior has been detected in a study done in the Tlalpan municipality, where the majority of people said to have lived in the very same municipality before moving to the informal settlement (Santos Cerquera et al., 2014).

### 3. Elements used to evaluate the vulnerability

As established by several actors (CONAPO, 2016), (Tyler and Moench, 2012), (Kelman et al., 2015), (IPCC, 2014) vulnerability is a consequence of several factors and the relationship in between them. Such as the social classes (López-Calva and Ortiz-Juarez, 2014), livelihood (Hahn et al., 2009), physical environment and location (Papathoma-Köhle et al., 2011) among other elements. The severity and impact on population caused by done by natural phenomenon are likely to vary geographically (Uitto, 1998). Moreover, the nature and degree of vulnerability are likely to

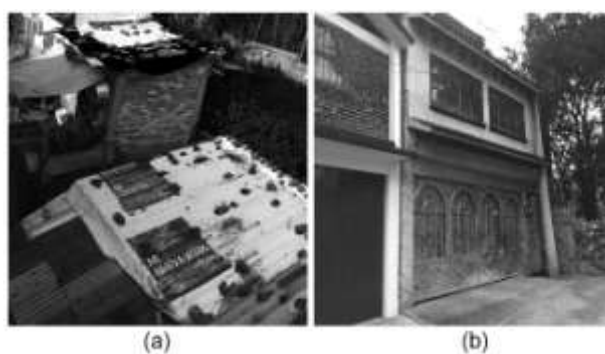


Figure 1

vary amongst individuals, groups, or households (Santos Cerquera et al., 2014).

Vulnerability assessments can help decision-makers understand the elements and complexity of vulnerability phenomena across scales and provide insights that can assist in the development of policy and actions to tackle the problem (Marshall et al., 2014). Jordán and Martínez (2009) discuss the possibility to create a list of elements that could define the degree of vulnerability of the inhabitants through a combination of academic review, field data, and empiric testing, in each home. The resulting list of elements to process in the presented formula includes the economic

capacity to face an altering event of natural or manmade origin, and the ability of the household to stand and continue to serve after a major incident happens. The numeric result of the application of the formula gets compared with a scale that represents the local hazards and the likelihood of hazardous events happening to the population.

The local situation in Mexico City compels to establish a straightforward but reliable scale of vulnerability to be mixed with the designated scale, which may come from the local legal framework. Therefore, the capability of the formula should include a translation method to accommodate the local needs, which may also change as time passes.

The following paragraphs describe the elements used in the construction of the presented formula; these come from an academic review and the local laws in Mexico.

### ***3.1. Construction Quality of each house***

The first element is a summary of the physical characteristics and construction quality of the house and its structural elements. The elements that describe the degree of vulnerability or resilience come from the construction quality. These include a proper foundation, as well as loading walls, and beams (outrigger beam, ceiling beam, cross beam, and needle beam) (Santos Cerquera et al., 2014). The better quality of the evaluated house and the completeness of its structure gets a more resilient value. A well laid and adequately constructed house receives the best possible grade (Figure 2(a)). A house with a ceiling made of non-permanent materials, such as aluminum plates or any similar solution, but with a proper structure, such as brick walls, gets a medium grade (Figure 2(b)).

Lastly, a house built entirely with non-permanent materials is qualified with the worst grade (Figure 2(c)). The parameter can be adjusted accordingly to the local needs of the legal framework.

### ***3.2. The education level of the inhabitants***



Figure 2

The education levels of the inhabitants in a particular community or household play a significant weight on the assigned value, it summaries social and cultural conditions in a single variable. The reliability of is the variable gets weighing by considering the local situation. A typical example for weighing this variable is the potential gap between rural and urban education systems. It is advised to consult local studies to set the weight and scale of the education level of the inhabitants, like the work done by Espinoza et al. (2014).The quoted paper contains a comprehensive study of the

school attendance and the relationship with governmental programs. The information is used to measure two factors. The first is the effectiveness of such programs to prevent dropping out from school, as well as reintegration to the scholar system. The second, is the positive impact on the local communities, from a perspective of economy, life quality, and political participation. Another essential idea to consider at the moment of establishing the scale in this item is the capacity and ease of the target population to access information regarding important concepts (Arauz, 2017) that may play an important role in case of a natural disaster.

### ***3.3. Number of older adults or small children***

The socio-demographic characteristics of individuals can define a specific degree of vulnerability to most life-altering situations, such as gender, age, and their physical and material conditions, such as illness or incapacity. It should be documented the inhabitants with any particular need to address the vulnerability of a community or household in a proper fashion, due to illness or age, either very young infants (Morrow, 1999) or elderly (Jia et al., 2010) persons. This information is essential in a proper effort to quantify vulnerability. Failing to include this information would immediately result in an enormous gap between the final score and the actual conditions of the studied community or group.

### ***3.4. House Overcrowding***

Overcrowding levels rise in the periphery of the metropolitan zones (Vargas Fernández and Rodríguez Sosa, 2016), finding an increase of 140% of inhabitants in comparison with the rest of the population (using data from INEGI and Tomas (1997)). This increase is linked to the population in the lower income tiers, who find an opportunity to own property in the outer zones of the cities, as a countermeasure to the low salary of each of the inhabitants (Tomas, 1997). The factor of vulnerability caused by overcrowding is measured in two parts, the first by the number of inhabitants per household; the second is the number of persons per bedroom. The resulting category is the outcome of using a mathematical formula, categorized on a discrete scale.

### ***3.5. Household income***

The household income vulnerability is measured against the national minimum salary established by the local labor law. The calculation is done considering factors established by a government entity (CONAPO) entitled to the tasks of handling the population growth and designing programs to steer it towards a beneficial figure for the national wellbeing. This variable is linked partially to the acquisition process of the lands in the informal settlement; the location in unfit terrains for housing development and legal impossibility of using such lands for housing purposes, this results in low asking prices and an informal system for periodical payments.

## **4. A formula for measuring vulnerability**

The presented formula has to comply with the local policy, in the case of Mexico the related policy is ruled by the National Population Council (Consejo Nacional de Población, CONAPO), as well as the attention and measurement at a national level. The definition of vulnerability is as follows:

As the weakness that communities, homes, and individuals face due to a lack of material and non-

material resources, to face external and internal changes and transformations of the immediate surroundings (CONAPO, 2016).

In the specific case of Mexico City, the local regulation requires the use of a category in the format of a traffic light, indicating the largest amount or value linked to the vulnerability, or lack of resilience to the red, the middle values in yellow, and the least vulnerable and more resilience in green. A recent modification, demands the use of a five-step scale, resulting in the following divisions:

- (1) Red – Highest value of vulnerability
- (2) Orange – the Higher value of vulnerability
- (3) Yellow – the Mediumvalue of vulnerability
- (4) Green – Lower value of vulnerability
- (5) Light green– lowest value of vulnerability

The formula is designed to use all the evaluated elements in numeric values, which are scalar representations of another type of variables. To achieve the necessary flexibility and adapt to any changes in the local regulation or use in a different region with its local laws. Allowing for full customization of the formula to attend any situation or scenario.

Accordingly, to be designed as simple as possible, the formula is as follows:

The application of the formula ranges from a household level to full neighborhoods, given the

$$Vul = (income_v * 0.6) + (education_v * 0.6) + (overcrowding_v * 0.4) \\ + (age_v * 0.4) + (construction_v)$$

proper treatment of the formula and data. Moreover, how the results are classified will depend on the use case.

#### ***4.1. The reasoning for the weighting***

During the projects, the most obvious and truthful variable to describe vulnerability is the construction quality of the household. It is in many cases an indirect reference to the income and education variables; the better the quality of a house, the better education, and income, as well as less overcrowding. This **consideration** places the construction quality in the highest tier of the weighting with the unit. The **income** and **education** variables are treated in a second tier, with a weight of 0.6; as the minimum grades of these qualities are reflected in the construction. However, in the case of a variable exceeding the ones represented in the construction quality, they are included as a lower value in the overall vulnerability calculation. The lowest tier, with a weighting of 0.4, contains the **overcrowding** and **age** variables. Since these usually play a tipping role in jumping from a medium to high vulnerability or a high to a higher one.

4.2. Application of the formula

The next paragraphs will contain an example of the usage of the formula. In a theoretical household with a family composed of six persons (**Error! Reference source not found.**(a) and (b)) with the following characteristics, the vulnerability would be considered medium.

Person	Name	Income	Education
1	Maria	\$10,000 MXN/month	middle school
2	Luis	\$15,000 MXN/month	undergraduate studies
3	Jorge	\$ 7,000 MXN/month	undergraduate studies
4	Ana	NA	high school
5	Karla	NA	middle school
6	Veronica	NA	elementary

(a)

House
3 Rooms
Good construction quality

(b)

Person	Education	Result Value
1	middle school	4
2	undergraduate studies	1
3	undergraduate studies	1
4	high school	3
6	elementary	5

(c)

Person	Education	Result Value
5	middle school	1

(d)

Range	Vulnerability/Category	Result Value
Less Than \$2,500 MXN/month	Highest / Poor	5
\$2,500 to \$5,000 MXN/month	Higher/Low mid	4
\$5,000 to \$6,000 MXN/month	Mid/Mid and Lower	3
\$6,000 to \$10,000 MXN/month	Low/Mid and High	2
More than \$10,000 MXN/month	Lowest / Rich	1

(e)

Education	Vulnerability/Category	Result Value
no schooling	Highest vulnerability	6
elementary	Highest vulnerability	5
middle school	Higher vulnerability	4
high school	Medium vulnerability	3
technical	Low vulnerability	2
undergraduate studies	Low vulnerability	1
postgraduate	Lowest vulnerability	1
doctorate	Lowest vulnerability	1

(b)

Education	Vulnerability/Category	Result Value
no schooling	Highest vulnerability	6
elementary	Higher vulnerability	5
middle school	Lowest vulnerability	1
high school	Lowest vulnerability	1

(c)

Education	Vulnerability/Category	Result Value
no schooling	Highest vulnerability	6
elementary	Lowest vulnerability	1
middle school	Lowest vulnerability	1

(d)

Calculated Value	Vulnerability/Category	Result Value
3 or more	High vulnerability	6
2.4 to 3	Medium vulnerability	3
Less than 2.4	Low vulnerability	1

(e)

Calculated Value	Vulnerability/Category	Result Value
More than 2.2	High vulnerability	3
Less than 2.2	Low vulnerability	1

(f)

Presence of	Vulnerability/Category	Result Value
Elderly or small children	High vulnerability	3
No elderly or small children	Low vulnerability	1

(g)

Characteristics of the house	Vulnerability/Category	Result Value
Non-permanent materials.	High vulnerability	6
Lack of a concrete ceiling but with a proper foundation, as well as loading walls, and beams.	Medium vulnerability	3
Proper foundation, as well as loading walls, beams, and concrete ceiling.	Low vulnerability	1

(h)

Value	Vulnerability
More than 14.8	Highest / Red
10.7 to 14.8	High / Orange
6.3 to 10.7	Medium / Yellow
4.3 to 6.3	Low / Green
Less than 4.3	Lowest / Light green

(i)

Figure 3



**Income:** the total income is added into a single pot and then is divided into each member.

$$\$15\,000 + \$10\,000 + \$7\,000 = 32\,000$$

$$\$32\,000 / 6 = \$5\,333$$

The individual amount of money per month is compared with the Figure 3 (a), this table can be deduced or use any local evaluation format.

This household gets a category of Mid/Mid-Lower and a value of **3**.

**Education:** The vulnerability is calculated first at an individual level and then the average value classified is assigned to the household. This variable is compared with the appropriate table according to the corresponding age group. The data of the adult subject to be evaluated is presented in **Error! Reference source not found.** (c) and compared with the table Figure 3 (b). For persons in between 15 to 18 years old, the following table in Figure 3 (c) is used, in this case, it is not used. For children in school age and younger than 15 years old Figure 3 (d) is used, the data for this exercise is shown in **Error! Reference source not found.** (d). The results are added and the

$$\text{The average is: } 4 + 1 + 1 + 3 + 5 + 1 = 15$$

$$15 / 6 = 2.5$$

The average result is compared with Figure 3 (e).

This household gets a category of Medium and a value of **3**.

**Overcrowding:** The number of people is divided by the number of rooms:

$$6 / 3 = 2$$

The result is compared with the Figure 3 (f):

This household gets a category of Low and a value of **1**.

**Age:** In case of any presence of any elderly or little children the vulnerability is assigned using the Figure 3 (g).

This household gets a category of High and a value of **3**.

**Construction:** The construction quality is evaluated with the Figure 3 (h).

This household gets a category of Medium and a value of **3**.

**Vulnerability calculation:** the calculation of the vulnerability is used with the calculated variables: Moreover, the result is evaluated using the Figure 3 (i).

The example household gets a **Medium/Yellow category**.

$$Vul = (3 * 0.6) + (3 * 0.6) + (1 * 0.4) + (3 * 0.4) + (1)$$

$$Vul = 6.2$$

## 5. Scenarios to apply the formula

### 5.1. Regulation of the land use occupied by the settlement

The present formula is a product of several projects undertaken by the research group involving the regulation and land use change of informal settlements located in the green belt of Mexico City. These settlements are subject of a special ruling that allows for such a change of land use supported with the proper studies that demonstrate the current urban status of each settlement.

Having a detailed profile of the degree of vulnerability in the local inhabitants and the environmental status of the surrounding areas is an essential tool for the planning in the attention process of the area. With the precise knowledge of what elements hinder the reliance of local groups, a proper profile of the target populations it is possible to get better management of campaigns of mitigation of the environmental impact, or even relocation process are feasible

options. Furthermore, it can assist to choose how to develop specific areas and prevent social decline.

### ***5.2. Design of social welfare programs***

The design process for welfare programs can benefit from a reliable vulnerability scale to set goals and strategies. In conjunction with proper participatory planning, the presented formula can point directly to have elements are generating vulnerability in specific populations. This knowledge can help to choose the best action route for tackling the social gaps and achieve sustainable solutions from the involved actors (Martorell et al., 2003). The capability of breaking down vulnerability, from a general concept and understanding how peculiar elements contribute to its predominance in specific groups, should help in the design process of social welfare and improvement programs. Avoiding programs that help topics or elements where there is no need to intervene, but a less detailed inspection suggests to do so.

### ***5.3. Building resilient urban systems***

Every urban space poses a certain degree of vulnerability to disasters, and it should possess features of resilience and feasibility (Godschalk, 2003). The present formula can help city planners and decision makers to establish clear action plans and social programs, by focusing on the vulnerable populations. Moreover, be prepared to handle events or disasters that alter the daily life in their urban centers. In conjunction with public participation, this formula can help boost city resilience, and help to shape the interests of the involved stakeholders and assign different values to the vulnerability calculation process (Lebel et al., 2006).

The main advantage of this formula is how it can be adapted to fit most scenarios, from urban to rural. The last one requires a different set of policies; rural livelihoods are more susceptible to natural disasters and climate change (Tanner et al., 2009). Therefore the associated vulnerability should be handled with the appropriated optics.

## **6. Conclusions**

Finding a balance in between reasonable urban sprawl and environmental protection is a complex task, it needs a broad set of tools and studies to support the decision-making process that settles how a city can grow without endangering its conservation lands, green spaces, and the services they provide. The planners inside the government, private sector, and academy must address this process, using structured and reliable knowledge and a deep understanding of the local and global conditions at hand.

The described formula is a tool to measure vulnerability in human societies, conceived as a flexible and sensible to the place, environment, and local legal framework. The weighing and variables are subject to changes to comply with the needs of the application. It offers the possibility to add or reduce the number of variables and the importance of each one. Furthermore, the scale of use can change from individual households to blocks or neighbourhoods; this feature gives the opportunity from a spatial perspective, to address specific conditions or characteristics in specific the elements or groups that in the global value of vulnerability may hinder the obtained result. Opening actions paths to work with individual variables through social programs.

When dealing with informal urban sprawl handling the vulnerability requires a different approach compared to the rest of the urban fabric. The social composition, while equally heterogeneous as the rest of the city, is usually a host of severe problems due to the lack of public services like water, drainage, electricity or waste collection; and the ways that the locals solve them. The most common solutions fall in the insufficient or illegal sides; create situations where the vulnerability is multiplied by a lack of sanitation or capacity to react to a hazardous happening. Therefore, it is not possible to compare the formal urban spaces within a city with the informal sprawls. Special planning considering the complexity between environmental and social factors is the path to find the proper solutions.

The first consideration when adapting the formula is the local legal framework, what parameters exist for measuring vulnerability and the elements or factors that integrate it. When setting scales for construction quality, education levels, age groups, overcrowding, and income, all measurement scales should consider the applicable law, if it exists. In such cases, or to fine tune the existing ones, research on academic documents can help to improve or develop measurement scales.

The second consideration is the source of the data used to calculate the value and category of vulnerability. The quality and reliability of the data may alter the weighing and interaction of the elements. The ideal data source is plain fieldwork, with custom-made questionnaires, applied in a door to door survey on the interest areas. The questionnaires must be simple, avoiding open questions, and include geographical coordinates for control. If it is not possible to apply a questionnaire to obtain first-hand data, a reliable option is the official census data. The date of the census and the necessary projections to get updated estimates are points to observe in the general adjustment of the formula. In both cases, data should pass a comprehensive review for quality control and veracity.

The number of elements in the formula can be modified, to accommodate the variables that better represent local conditions or are available for use. The weighing of each element must change to compensate. These changes may come from interviews, academic literature or local laws and frameworks.

How the resulting numeric value of the formula is catalogued is also subject to the conditions of the formula adjustment. Using local and international standards to set the limits for the categories is as valid as working with the ones used in this article. However, the new categories or degrees should not be set to mask vulnerability. Instead, the new categories have to separate specific groups, with special needs, that in a more general exercise might be mixed or generalized.

Resilience is a crucial point in the political agenda of many governments and international agencies, the success of the practical application of policies and programs depends directly on the understanding the nature and characteristics of the populations in potential danger. The formula shown in this paper is an adaptive tool to understand and measure the different degrees of vulnerability and what is causing such phenomena.

## 7. References

Aguilar A-G (2018) La reorientación de flujos migratorios en la ciudad-región. El caso de la Ciudad de México en la Región Centro. *Revista EURE-Revista de Estudios Urbano Regionales* 44(133): 51–57.

- Arauz ER (2017) ESCENARIOS NO ESCOLARES DE APRENDIZAJE Y GRUPOS EN SITUACIÓN DE VULNERABILIDAD. *Revista Digital Universitaria, UNAM* 17(1).
- Artiles DM and Olivera A (2007) CALIDAD Y DESEMPEÑO DURABLE DE LAS VIVIENDAS. LA PERCEPCIÓN DE SUS RESIDENTES. *Arquitectura y Urbanismo* XXVIII(2): 34–39.
- Bailey C and Zenteno E (2015) Reflexiones en torno a la vulnerabilidad social y residencial de los asentamiento informales de los cerros de Valparaíso, Chile. *CIDADES, Comunidades e Territórios* (31): 116–130.
- Brassett J, Croft S and Vaughan-Williams N (2013) Introduction: An Agenda for Resilience Research in Politics and International Relations. *POLITICS* 33(4): 221–228.
- Caraveo B (2009) El problema de la vivienda en Ciudad Juárez: los asentamientos humanos irregulares. *Nóesis. Revista de Ciencias Sociales y Humanidades* 18(36): 156–167.
- Cardona OD (2002) La necesidad de repensar de manera holística los conceptos de vulnerabilidad y riesgo.
- Castro NG and Salinas SV (2016) Los niveles de vulnerabilidad social de la Ciudad de Chilpancingo, Guerrero, México. *Revista Geográfica de América Central* 1(56): 259–288.
- CONAPO (2016) *La condición de ubicación geográfica de las localidades menores a 2 500 habitantes en México*. Ciudad de México.
- Conti B De (2014) Brasil : Fortalecimiento de la Resiliencia Mediante una Estrategia Innovadora Basada en los Ingresos. *International Policy Centre for Inclusive Growth* (253): 2002–2003.
- Espinoza O, Castillo D, Gonzalez L, et al. (2014) Educación de adultos e inclusión social en Chile. *Psicoperspectivas* 13(3): 69–81. DOI: 10.5027/PSICOPERSPECTIVAS-VOL13-ISSUE3-FULLTEXT-393.
- G. Aguilar A and López FM (2016) Espacios de pobreza en la periferia urbana y suburbios interiores de la Ciudad de México. Las desventajas acumuladas. *Economía Informa* 42(125): 5–29.
- Giezen M, Bertolini L and Salet W (2015) Adaptive Capacity Within a Mega Project: A Case Study on Planning and Decision-Making in the Face of Complexity. *European Planning Studies* 23(5): 999–1018.
- Godschalk DR (2003) Urban Hazard Mitigation: Creating Resilient Cities. *Natural hazards review* 4(3): 136–143.

- Hahn MB, Riederer AM and Foster SO (2009) The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. *Global Environmental Change* 19(1): 74–88.
- Instituto de Geografía U (2011) *Atlas de Peligros Naturales o Riesgos de la Delegación Tlalpan*. Mexico City. Available at:  
[http://www.inapam.gob.mx/work/models/SEDESOL/Resource/2612/Atlas\\_Estados/09012\\_TLALPAN/Atlas\\_Peligros\\_Riesgos\\_Tlalpan\\_2011.pdf](http://www.inapam.gob.mx/work/models/SEDESOL/Resource/2612/Atlas_Estados/09012_TLALPAN/Atlas_Peligros_Riesgos_Tlalpan_2011.pdf).
- IPCC (2014) Summary for policymakers. In: Field CB, Barros VR, Dokken DJ, et al. (eds) *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Cambridge University Press, pp. 1–32.
- Jia Z, Tian W, Liu W, et al. (2010) Are the elderly more vulnerable to psychological impact of natural disaster? A population-based survey of adult survivors of the 2008 Sichuan earthquake. *BMC Public Health* 10(1).
- Jordán R and Martínez R (2009) *Pobreza y precariedad urbana en América Latina y el Caribe. Situación actual y financiamiento de políticas y programas*. Comisión Económica para América Latina y el Caribe (ed.). Santiago de Chile: Naciones Unidas.
- Kelman I, Gaillard J and Mercer J (2015) Climate Change's Role in Disaster Risk Reduction's Future Beyond Vulnerability and Resilience. *International Journal of Disaster Risk Science* 6(1): 21–27.
- L. Cutter S, J. Boruff B and Shirley WL (2003) Social Vulnerability to Environmental Hazards. *Social science quarterly* 84(2): 242–261.
- Lebel L, Anderies JM, Campbell B, et al. (2006) Governance and the Capacity to Manage Resilience in Regional Social-Ecological Systems. *Marine Sciences Faculty Scholarship* 11(1).
- López-Calva LF and Ortiz-Juarez E (2014) A vulnerability approach to the definition of the middle class. *The Journal of Economic Inequality* 12(1): 23–47.
- Marshall NA, Stokes CJ, Webbc NP, et al. (2014) Social vulnerability to climate change in primary producers: A typology approach. *Agriculture, Ecosystems & Environment* 186: 86–93.
- Martorell O, Ben Altabef C, Nallar H, et al. (2003) La Gestión Social del Estado, Políticas de Intervención en el Hábitat Popular Urbano. El Programa de Atención de Grupos Vulnerables. *Revista INVI* 18(46): 97–123.
- Morrow BH (1999) Identifying and Mapping Community Vulnerability. *Disasters* 21(1): 1–8.

- Papathoma-Köhle M, Kappes M, Keiler M, et al. (2011) Physical vulnerability assessment for alpine hazards state of the art and future needs. *Natural Hazards* 58(2): 645–680.
- Patarasuk R, Gurney KR, O’Keeffe D, et al. (2016) Urban high-resolution fossil fuel CO2 emissions quantification and exploration of emission drivers for potential policy applications. *Urban ecosystems* 19(3): 1013–1039.
- Pérez-Campuzano E and Santos-Cerquera C (2013) Tendencias recientes de la migración interna en México. *Papeles de Poblacion* 19(76): 53–88. DOI: 14057425.
- Pérez Campuzano E and Santos Cerquera C (2011) Diferenciación socioespacial en la Zona Metropolitana de la Ciudad de México Sociospatial segregation in the Metropolitan Zone of Mexico City. *Investigaciones geográficas* (74): 92–106.
- Roo G De (2017) Ordering Principles in a Dynamic World of Change – On social complexity, transformation and the conditions for balancing purposeful interventions and spontaneous change. *Progress in Planning*.
- Sánchez-Vega JT, Tay-Zavala J, Robert-Guerrero L, et al. (2000) Frecuencia de parasitosis intestinales en asentamientos humanos irregulares. *Revista de la Facultad de Medicina UNAM* 43(3): 80–83.
- Santos Cerquera C (2013) Interacciones y Tensiones entre la Expansión Urbana y el Suelo de Conservación. In: Aguilar AG and Escamilla Herrera I (eds) *La Sustentabilidad en la Ciudad de México*. Primera Ed. Ciudad de México: Porrúa, pp. 67–108.
- Santos Cerquera C, Ortiz Meraz O, Ávila Cedillo R, et al. (2014) *Análisis Físico Territorial para el Control y Tratamiento de los Asentamientos Humanos Irregulares en Suelo de Conservación, Caso de Estudio San Miguel Topilejo, Delegación Tlalpan, Distrito Federal*. Ciudad de México.
- Schteingart M and Salaza C (2003) Expansión urbana, protección ambiental y actores sociales en la Ciudad de México. *Estudios Demográficos y Urbanos* 18(3): 433–460.
- Stålsett SJ (2004) Vulnerabilidad, dignidad y justicia: Valores éticos fundamentales en un mundo globalizado. *Revista Venezolana de Gerencia* 9(25).
- Tacoli C (1998) Rural-urban interactions: a guide to the literature. *Environment and Urbanization* 19(1): 147–166. DOI: <https://doi.org/10.1177/095624789801000105>.
- Tanner T, Mitchell T, Polack E, et al. (2009) Urban Governance for Adaptation: Assessing Climate Change Resilience in Ten Asian Cities. *IDS Working Papers* 2009(315): 01-47. DOI: 10.1111/j.2040-0209.2009.00315\_2.x.

- Tomas F (1997) Los asentamientos populares irregulares en las periferias urbanas de América Latina. In: Azuela A and Tomas F (eds) *El acceso de los pobres al suelo urbano*. Primera Ed. Ciudad de México: PUEC, IIS y Centro Francés de Estudios Mexicanos y Centroamericanos (CEMCA), pp. 17–43.
- Tonon G (2010) La utilización de indicadores de calidad de vida para la decisión de políticas públicas. *Revista de la Universidad Bolivariana* 9(26): 361–370.
- Tyler S and Moench M (2012) A framework for urban climate resilience. *Climate and Development* 4(4): 311–326. DOI: 10.1080/17565529.2012.745389.
- Uitto JI (1998) The geography of disaster vulnerability in megacities: A theoretical framework. *Applied Geography* 18(1): 7–16.
- Valdebenito Valdebenito CE (2014) EL LUGAR DE RESIDENCIA DE LOS POBRES EN UNA CIUDAD PRÓSPERA. EL CASO DE LOS ASENTAMIENTOS HUMANOS IRREGULARES EN VIÑA DEL MAR-CHILE. *Scripta Nova. Revista Electrónica de Geografía y Ciencias sociales* 26(493): 1–13.
- Vargas Fernández CG and Rodríguez Sosa M (2016) Aceptabilidad social , forma urbana y sustentabilidad de barrios urbanos en Ciudad Juárez , Chihuahua. *OPERA* (19): 111–137.
- Wong CP, Jiang B, Kinzig AP, et al. (2015) Linking ecosystem characteristics to final ecosystem services for public policy. *Ecology letters* 18(1): 108–118.