Quantifying the Social Aspects of Disaster Vulnerability

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Abstract

This study proposes a new risk index **R** which considers the social aspect in equation form:

$$\text{Total Risk } \underline{R} = \sum_{i=1,j=1,k=1}^{n\ \ n\ \ n} w_i H_i^*(\alpha_{ijk}) w_j V_{ij}$$

where (α_{ijk}) is the social factor parameter that increases or decreases the hard vulnerability, w_j is the weight of a physical vulnerability factor to the total physical vulnerability factors and w_i is the weight given to a hazard of a certain type with respect to all hazards considered. Each of the weights w_i and w_j should add to1.0

A framework for assessing disaster risk that considers the social aspect of disaster vulnerability and its quantification in the risk equation is presented. Initial work shows that this decision making tool can be part of a planner's tools, but more research is needed to validate its applicability in various settings of hazards and vulnerabilities.

The risk equation

The impact of nature's induced forces such as flooding, typhoons, land ground movement, tsunami, liquefaction effects to man's built environment and to societal organizations had been known to be disastrous. The probability of occurrence of these hazards can be determined using probability concepts, but the risks it bring about varies among the different sectors (e.g. socio-political, financial, and security). The measures to describe impact on these sectors are different, since the concerns vary with each group. Among such measures is to use a statement of risk that combines the magnitude of the natural hazard and the vulnerability of the exposed elements at a determined moment. In expression form,

Risk = *function* (hazard, vulnerability)

Depending on the type of risk assessment, the expression can only suggest an approach in qualifying and even quantifying what adds up to a risk. For economist, the risk can be a measure of the damages in terms of monetary units, where a particular hazard, in terms of a probability distribution of magnitude and occurrence and the vulnerability in terms of the unit damage cost for a certain element considered. For physical and social planners, disaster mitigation and preparation are important aspects of development planning. In a book " Disaster Mitigation, A Community Based Approach,[1]

Risk = Hazard + Vulnerability

This expression may indicate that disasters are characteristics of a natural hazard and another that disasters are characteristics not of hazards, but of socio-economic and political structures and processes. This adds up to the risk. Another formulation states that risk is a result of the

[1] Development Guidelines No.3, Andrew Maskrey

interaction of both and there is no risk a) if there are hazards (H) but vulnerability (V) is nil, or b) if there is a vulnerable population but no hazard event. In a simple expression form,

Risk R = H * V

In cases that many vulnerability factors contribute to a hazard or a set of hazards, the total risk can be expressed as

$$\textbf{Total Risk } R = \sum_{i=1,j=1}^{n\ \ n} w_i H_i * w_j V_{ij}$$

where H_i represents the different hazards, and the V_{ij} represents the different vulnerabilities corresponding to these hazards. The wj is a weight of importance of a selected physical vulnerability factor to all physical vulnerability factors considered and w_i is the weight given to a hazard of a certain type with respect to all hazards considered. Each of the weights w_i and w_j should add to1.0. The value or risk is normalized.

However, this type of risk equation is usually based on hard vulnerabilities (potential to damage of a certain type of construction-e.g reinforced concrete, etc under a certain magnitude of an earthquake) and for planners, its use is limited simply because the risk misses out the social aspects like for example, occupancy, age and condition of the occupants which can modify it.

The problem of quantifying the social factor

How do we measure the social vulnerability of a community against a natural disastrous event? Qualitatively, we can simply describe it in sentences. We can also set a scale or a set of categories to differentiate among people on any one variable. In a dichotomous set-up, when we categorize a person or community as "not vulnerable" or "vulnerable" we can assign numbers 0 or 1 indicating the absence or presence of the vulnerability.

A more important question is under what circumstances can we say that a person is "vulnerable" or not? Is the distinction clear or "fuzzy"?

We can set the scale of categories in order by rank on a certain scale or continuum, say for example, we can order vulnerability in terms of how much support a community can expect from others:

1=least vulnerable (e.g. active religious groups, active non-government organizations, active neighborhood groups, barangay brigade available, friends and relatives)
2=moderately vulnerable (e.g. friends and relatives are present to help)
3=most vulnerable (e.g. no help)

The scale states that 1 means lesser vulnerability because "more" outside help is available than 3 and 2 is located in between. Such scale gives only information but does not provide any information about distances between the values. We might wonder how many NGOs or active neighborhood groups or watchmen are needed to qualify in 1 or 2 or 3? This scale does not even imply anything about arithmetical values other than they are in order.

If the interval between 1,2 and 3 represent equal quantities of the variable measured, then they make up an interval scale. In the present problem, the difficulty now is determining what arrangements of assistance provide for an equal distance in the scale? Unlike integers (an

interval scale), we know that these numbers can be added or subtracted because their properties tell us that 60-40= 40-20. But does the difference between forty and sixty people carry the same weight compared to a difference between twenty to forty people helping? Does the interval scale carry the same meaning?

Does the present ranking of categories also suggest that those categorized in 3 is three times more vulnerable than those in 1? The scale does not suggest it even if 0 were added in the scale (a ratio scale). So why do we to put numbers in describing social vulnerability? People have different levels of awareness of hazards and they have different degrees of vulnerabilities. Because of the different scales upon which a criteria are measured, it is necessary that factors that establish vulnerability be standardized or "normalized". This makes it amenable for comparison with other factors. This also makes it possible to enter the risk equation.

An analysis tool for decision strategies

Decision framework
Among the concerns involved in vulnerability analysis is assigning individuals or communities to a certain decision set. A scale of issues may be made based from a review of damage reports, interviews and surveys, common observations from which the elements considered may be categorized and scored. These issues are then correlated to a range of consequences (e.g. damage to property, injury to person, the potential disruption to a person's livelihood) that had resulted or could result from (possibility or potential) being exposed to a particular hazard(e.g. flooding, typhoon, ground shaking, liquefaction).

Each of the individual responses is then evaluated using the criteria (factor) established in the study and scored. The factors (e.g. the degree of safety, the ability to cope with a particular disaster) considered should be comprehensive to assess the condition of a person, family or bigger group depending on the scale of elements considered, e.g. sub-district or districts . The size or scale of the elements studied will depend on the objectives of the study. The scale proposed has a zero (0) to five (5) scale which carries the meaning of having least or zero vulnerability to being totally vulnerable with respect to the issue.

If the scores need to be aggregated, then simple averages or a frequency analysis on the number of responses towards a particular factor may be used to measure the "mean" or "dispersion" of the aggregated group over the scale established.

The scores could be normalized, by dividing the factor score by the maximum score of the scale. For example, should livelihood be decided to be scored "3" in a five (5) point scale, then it would be scored "0.6" in a "0 to 1" scale. If the rater believes that the scheme is simplistic, one can use frequency analysis and use probability distribution functions to standardize the scores. Though most logical, it may warrant more effort on the rater to decide on the distribution function, in addition to the problem of correlating unsafe conditions and the possible consequences of a hazard.

To select among the factors, a weighing scheme may be devised to establish rank and contribution to risk (or vulnerability) to a particular locality. As the weights are determined, other parameters of the risk equation may be evaluated and the risk value determined. The framework may be seen in figure 1 of the report.

Criterion
Establishing criterion means providing a basis for a decision that can be measured and evaluated. The damage reports, interviews and surveys, observations can provide the evidence upon which an individual or community may be assigned in a category. Examples of criteria matrices may be seen in the tables below. Column 3 of the tables shows the range of the scale considered for the factor. Column two shows the ranking of the issues and column three shows the values used to score a response.

The criteria used here may be **factors** or **constraints** that pertain to attributes of an individual or community.

The factor variables may be considered as the decision variables. For example-livelihood/ income, occupancy, nearness to a hazard area, accessibility of centers, state of health, and others could be factors that define the social aspect of vulnerability. It is a criterion that enhances or detracts from the vulnerability definition. Factors may or may not be measured on a continuous scale. The approach in this study is a stepped scale

The constraints limit the alternatives under consideration. An example is the exclusion of areas that are identified as prone to liquefaction or flood areas or landslide prone areas. Constraints can be evaluated using criteria established by various expert groups. The simplest constraint scheme may be a present or absent "1" and "0" decision rule.

Table 1. Effect to Livelihood/Income to Vulnerability

No.	Description	Descriptions to Consider
0	**No Effect**	Savings are available, Livelihood not affected by season,
1	**Slight Effect**	Savings available for use, Hazard slightly affecting work performance and corresponding income
2	**Minor Effect**	Savings may be available for use, hazard affects work performance, a lost work day Savings and/or earnings of a business are lost, Hazard affecting work performance, a lost work day or transaction
3	**Disruptive effect**	Continuous exposure to hazard creates difficulty/ a burden for the person or group Daily wage earner affected by natural events (construction worker, driver, vendor), No savings available for use Savings and/or earnings from business are lost. Takes a few days to fully recover lost deals
4	**Major Disruptive Effect**	Daily wage earner, affecting work performance in the longer term, such as prolonged absence from work Possibly affecting business, hazard creates a longer term problem to the business
5	**Irreversible Damage or effect to Livelihood**	Practically difficult to recover, loss of job or loss of business because of hazard

Table 2. Capacity to Get Medical Attention and Insurance Availability

No.	Description	Descriptions to Consider
0	**Very capable to get medical attention**	Can get services from most private hospitals. Owns an insurance policy and national health insurance. Most likely to have savings to pay for expenses even for serious injuries
1	**More than Capable to get medical attention**	Can get services from private or public hospitals. May or may not own an insurance policy but owns a national health insurance. Savings are substantial to cover major injuries.
2	**Capable to get medical attention**	Most of the time goes to public hospitals but c get services from private hospitals . Does not own an insurance policy but owns a national health insurance. Savings are limited to cover minor injuries.
3	**Moderately capable capacity to get medical attention**	Mostly get services from public hospitals or health centers. Does not own an insurance policy nor own a national health insurance. Savings are limited to cover emergencies involving minor injuries. The range of medical services needed may or may not be offered by the public hospital
4	**Limited capacity to get medical attention**	Mostly get services from public hospitals or health centers. They have no national health insurance and nor savings to cover emergencies. The range of medical services needed may not be offered by the public hospital nor by health center
5	**Cannot get medical attention at all**	Does not bother to seek medical attention because of condition, no financial capacity, gets services mainly by charity.

Table 3. Social Support to Safety

No.	Description	Descriptions to Consider
0	**Assistance is Immediate and Extensive**	Support is extended from a responsive local government unit, from a well organized NGO and community organizations, from friends and relatives, NGOs both in and out of the city Extent of support extends to rehabilitation and recovery
1	**Assistance may be limited from the city**	Support is extended immediately from the city but may be limited in terms of first aid, rescue and relief and temporary evacuation Nature of support concern rescue, relief Support from friends, barangay* heads and/or NGOs, neighborhood groups are available
2	**Assistance may be limited from the city and** **Assistance is limited from the neighborhood and barangay brigade**	neighborhood assistance and barangay present inspite of limited capability. Barangay finds difficulty in getting immediate support from the city government

3	**Limited Assistance**	Barangay assists, with limited capability.
4	**Minimal Assistance**	Help comes from Immediate Neighbors
5	**No help at all**	Nowhere to get help, not even from the barangay Don't know whom to seek help from

Note: barangay is a political unit composing a number of families

Decision rule and objectives

Vulnerability of a community (or an individual) is seldom one-dimensional but consists of several aspects that make up its physical, social, economic condition (even reputation). Prof. Wisner in his paper " Social Aspects of Earthquake Management "presents about ten aspects of social vulnerability (Wisner , 1998). To consider these aspects or part of it requires a procedure for combining them into a single composite index and a statement of how choices are to be compared using the index.

Decisions are guided by objectives and the rules are structured in the context of specific objectives. The approach presented can be modified depending on the objectives and views of the decision makers (intent and motives).The nature of the objective and the decision maker's motives define the structuring of the decision rule.

Evaluation

1) Multi-criteria evaluation

In this study, the approach involves a step criteria using a numeric range "0" to "5". The scores are combined using aggregation and simple averaging procedures. A weighted linear combination of factors can be made by applying weights to each factors. The results give a social vulnerability index to a certain physical vulnerability.

$V = \Sigma w_i v_i$ where V = vulnerability
w_i = weight of factor i
v_i = criterion score for vulnerability factor i
or criterion score for safety factor i

The usefulness of this index is in the weights established to each criteria that shows which aspect is contributing more to the social vulnerability issue in the community studied.

2) Criterion scoring

It is necessary that factors be standardized before combining them in the risk equation. The easiest is to use the maximum and minimum values as scaling points. This linear scaling may give

$X_i = (R_i - R_{min})/(R_{max} - R_{min})$ * standardized range where R = raw score

For example, in a zero to five (0-5) scale, if a factor receives a raw score of 4, then in a standardized range of 0 to 1, this would be (4-0)/ (5-0) = 0 .8.

However, there are issues to be considered in using the transformation rule given.

a. Thresholds or bounds of vulnerability

Do we know the thresholds (bounding limits) of the factors describing vulnerability? Lets use an example, say, trainings received in earthquake disaster preparedness. We may agree in principle that a person who has more trainings has a better chance of knowing what to do in case of a strong earthquake, than a person who probably have received a couple. All else being equal, how many trainings does one need to qualify him as "0" least vulnerable or "1" as most vulnerable. How many trainings is needed to qualify as "0.5"?

b. Establishing relationship between evidence and decision set

Sometimes we only have observations that show " apparent" correlation. For example, if we use savings as a basis for establishing vulnerability. Does it mean that those saving Peso 5000-10000 a month has a higher measure of safety than those saving PhP2000-PhP4999? Is the relationship direct?

c. Fuzziness in the measurable attributes

In the same example above, are the boundaries sharp? What's the difference of a peso or even a hundred peso between the intervals? Clearly there is no sharp boundary.

d. Multi criteria of vulnerability

To describe whether a community is socially vulnerable to a certain hazard one should look into various measures that would indicate higher or lesser vulnerabilities or unsafe conditions. Measures such as occupancy, nearness to a hazard area, accessibility of centers, state of health, perception to risk and others can have many measures.

e. Standardization of the factors

Another issue in the standardization of factors is the choice of endpoints at which membership reaches 0.0 or 1.0 (or 0 to 255 byte scale for colors). In setting the critical points in the set membership function, it is important to consider their inherent meaning. For example, if distance is the main issue in understanding relationship of safety and nearness to an overflowing creek, will a distance of 10 meters from the bank be any different from 50 meters? If not, then the critical points would be 0 meters and 10 meters in a zero to one (0-1) scale. But then, would the correlation reflect a linear or non-linear one?

f. Multidimensionality of the vulnerability issue

It is difficult to use a single factor to describe vulnerability. Most often, a set of conditions are necessary to get a picture of the community's vulnerability.

Criterion weights
Assigning criteria weights in this study makes use of a simple pairing procedure utilizing a nine(9) step scale indicating *the relative scale of importance*. The rater selects a factor and places it as a standard issue giving it a value of one (1). The individual or group makes every possible pairing with the standard issue using the scale given.

1/9	1/7	1/5	1/3	1	3	5	7	9
extremely	very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely
Less important?				standard	More important?			

A normalized *scale of importance* is obtained by dividing each score by the highest rated factor considered. This provides a normalized score of each factor relative to the most important factor (having a score of 1). To establish a weight among the normalized scores, the sum is taken and the weights are obtained by dividing the normalized scores by their sum.

Example

A. In a certain barangay, inundation due to flooding was a big problem and because the residents were living near rivers, the physical vulnerability of the area was also high. Based on the interviews and surveys conducted, the following factors were considered important in deciding the safety of the community. The scores for a particular factor used a five point scale and were aggregated and averaged. Establish the relative weights of the factors in assessing an index of safety.

Improved livelihood (α_{11})= 4
Stronger enforcement of building/land use zoning (α_{12})=3.5
Having More affordable Hospitals (α_{13})=4.2
Concern for the Elderly (α_{14})= 3.7
Increased Access to Evacuation Centers (α_{15})= 3.0

Step 1. Normalize the factors to a "0-1" scale using the following equation

$X_i = (R_i-R_{min})/(R_{max}-R_{min})$ * standardized range where R = raw score

Improved livelihood = 0.8 (α_{11})
Stronger enforcement of building codes =0.7 (α_{12})
Having more affordable hospitals =0.84 (α_{13})
Concern for the elderly = 0.74 (α_{14})
Increased access to evacuation centers = 0.6 (α_{15})

Step 2. Decide on the weights of the factors. Based on a group evaluation, most sectors think that concern for the elderly is a basic issue. Other factors, relative to this basic issue are weighed

1/9	**1/7**	**1/5**	**1/3**	**1**	**3**	**5**	**7**	**9**
extremely	very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely
Less important?				**standard**	**More important?**			
				(α_{14})				
						(α_{11})		
					(α_{12})			
			(α_{15})					
				(α_{13})				

The highest score is 5 and a normalized weight of importance reveal

Improved livelihood = 5/5 = 1	(α_{11}) = 1
Stronger enforcement of building codes =3/5 =0.60	(α_{12}) = 0.60
Having More affordable Hospitals =1/5 =0.2	(α_{13}) = 0.20
Concern for the Elderly = 1/5 =0.2	(α_{14}) = 0.20
Increased Access to Evacuation Centers = (1/3)/5	(E) = 0.067

The sum of the normalized scores is 2.067. The weight are (α_{11})=0.484, (α_{12}) =0.29, (α_{13}) =(α_{14}) =.097, (α_{15}) =.032. The sum of (α_{12}) to (α_{15}) is 1.0.

The results reveal that an improved livelihood and stronger enforcement of building codes represent about - of the social vulnerability to the risk.

Problem B

Establish a weighted linear combination of the factors given in the previous problem.

Considering a scale of safety [safe =0 (*0.0*) and least safe=5.0 (*1.0*)], and the normal scores:

Improved livelihood = 0.8	(α_{11})
Stronger enforcement of building codes =0.7	(α_{12})
Having more affordable hospitals =0.84	(α_{13})
Concern for the elderly = 0.74	(α_{14})
Increased access to evacuation centers = 0.6	(α_{15})

What would be an cumulative social vulnerability index (α_1) considering the factors are all considered?

Step 1. The weighted linear combination reveal

social vulnerability index (α_1) =0.484(α_{11}) + 0.29(α_{12}) + 0.097(α_{13}) + 0.097(α_{14}) + 0.032(α_{15})

social vulnerability index (α_1) =0.484(0.8) + 0.29(0.7) + 0.097(0.84) + 0.097(0.74) + 0.032(0.6)

social vulnerability index (α_1) =.0.77

The meaning may indicate a moderately unsafe condition considering the factors are taken in the decision process.

Use in the risk equation
If the social factors are included in the risk equation, then,

$$\text{Total Risk } \underline{R} = \sum_{i=1,\, j=1,\, k=1}^{n\ \ n\ \ n} w_i H_i * (\alpha_{ijk}) w_j V_{ij}$$

And assuming that we are considering a single hazard and a single physical vulnerability, then the Risk may be set up in the following form using the results of the above sample problems:

Risk $\underline{R} = H_1 * (\alpha_{ijk}$ = social vulnerability index (α_1) =0.484(α_{11}) + 0.29(α_{12}) + 0.097(α_{13}) + 0.097(α_{14}) + 0.032(α_{15})) $*V_1$

Conclusions

The approach presented considers the inclusion of the social aspect of vulnerability as critical in risk assessment. A methodology was proposed to quantify social vulnerability that may be used by planners together with experts in the physical and social sciences. Much of the premise in the criteria formulation was based on the characteristics of a few cities in Metro Manila and more validation is needed to check and establish its validity in other places. Though it is expected that the conditions are different in different cties of the world, the approach may be used and later finer points may be established to make the scheme more robust.

References:

" Social Aspects of Earthquake Management ",Wisner. B, UNU/IDNDR RADIUS Workshop Tokyo, 24 June l998

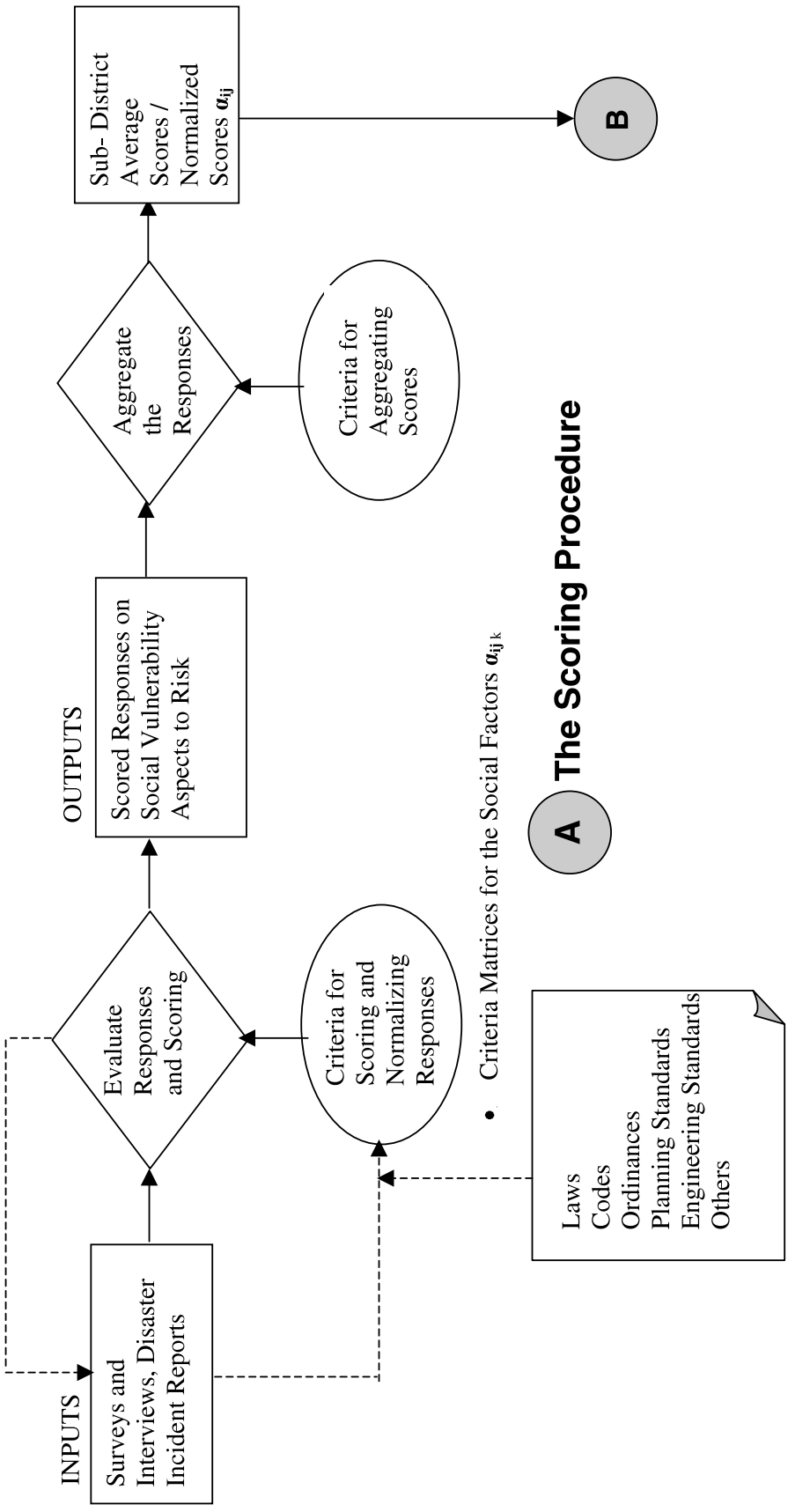
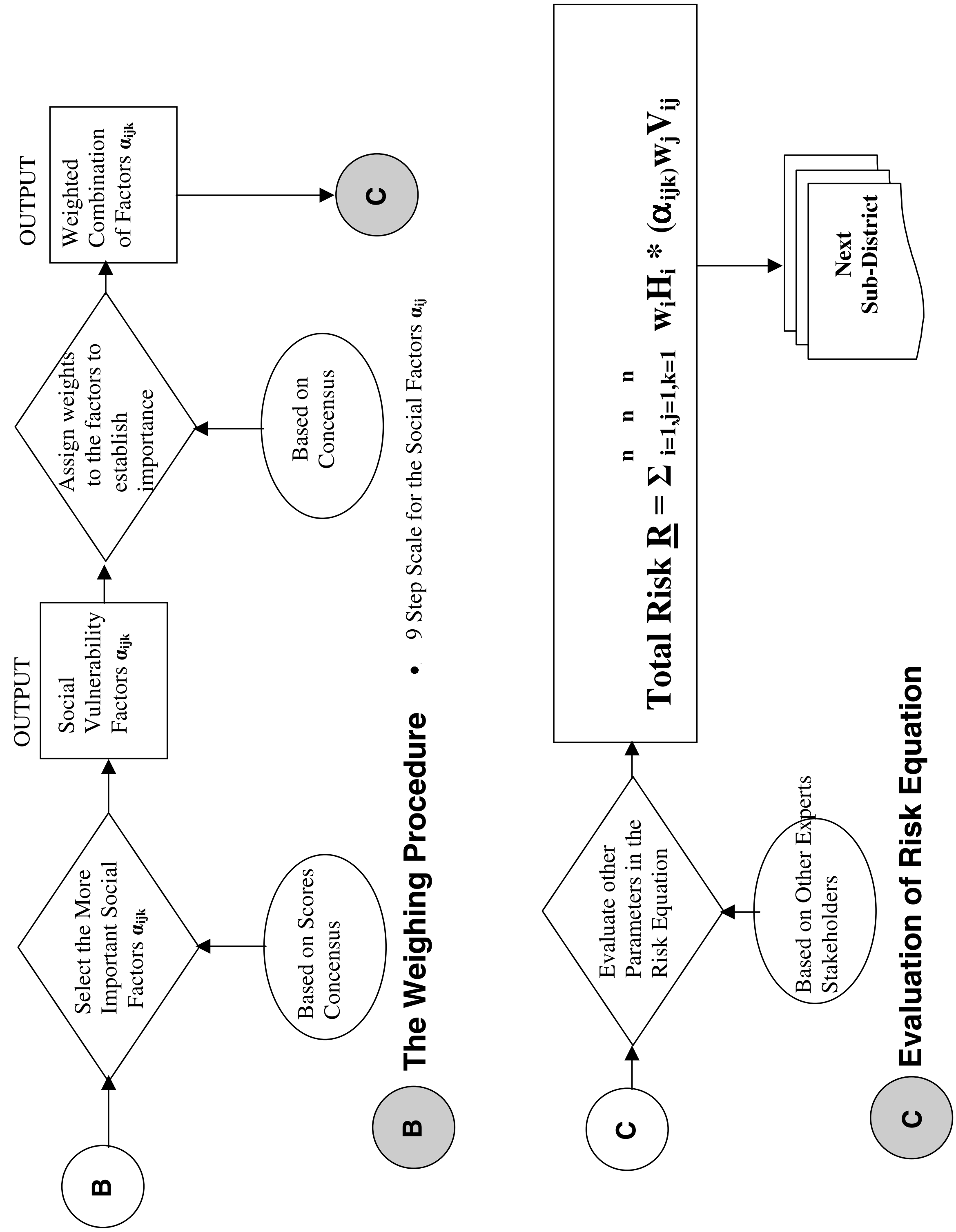


Figure 1. Framework for Assessing and Quantifying Social Vulnerability



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