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Importance of Vulnerability in Disaster Risk Management

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Abstract

Climate changes today result ever more frequently in large scale catastrophic events, such as floods, fires, tropical cyclones, hurricanes. They greatly endanger individuals, businesses and society as a whole. Countries, regions, local governments, and the insurance sector, have large problems resolving the consequences of such events. The likelihood of these events is difficult to influence. Nevertheless, the largest contribution to risk reduction can be achieved by reducing vulnerability in any of its four forms: infrastructural, environmental, economic and social vulnerability. This paper analyses different aspects and indicators for assessing vulnerability. The main aim in this paper is to show the importance of vulnerability assessment in disaster risk management. The main result of this research is vulnerability assessment method, methods like this one should contribute to shift from passive disaster-related defense to proactive disaster risk management, as well as from emergency management only, to disaster prevention, preparedness and mitigation activities.

Key words: *risk, vulnerability, hazard, catastrophe*

1. INTRODUCTION

Rapid, global and anthropogenically-driven climate change is occurring with measurable impacts and is likely to intensify extreme weather events and consequently increases disaster risk (Birkmann and Teichmann 2010) [1]. A disaster is a sudden harmful happening or an extreme unfortunate event which causes great harm to human beings and their property. Disasters occur quickly, with great intensity, at random, regardless of the time, place and degree of vulnerability of the affected area. These extreme events, either natural or caused by people, exceed the limit of tolerance at the time of occurence, make regulation of the situation very difficult and result in catastrophic losses of property and income. They complicate and aggravate the natural processes in the environment and cause catastrophic events for human society.

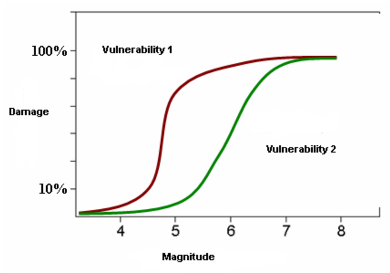
For example, tectonic movements of land may lead to earthquakes and volcanic eruptions, longer dry periods may lead to droughts and melting snow and heavy rains can result in flooding.

Disasters have always existed throughout the development of civilisation. Gradual development in material terms has resulted in alienation of man from nature on one hand. On the other hand, it has resulted in increasing vulnerability of human society. The increase in the number of lives lost and property destroyed, as well as adverse effects on the environment due to disasters, have forced the international community to adopt a new approach to risk management in case of events with catastrophic consequences. This approach goes beyond international borders, it anticipates possible threats and allows overcoming a disaster in its early stages. The nineteen nineties were declared the international decade for natural disaster reduction. Disaster proportions were established at the international level. It was necessary to establish a protocol that would allow help in case of disaster danger to be provided as soon as possible.

Disaster risk reduction, prevention and early warning do not exist in Serbia, so any effort in this direction is more than valuable. In our research, we put maximum effort into building the applicable vulnerability assessment method. In this paper, we present the theoretical basis of vulnerability, as well as the most important indicators of infrastructural facilities vulnerability to flooding, as part of vulnerability assessment method.

2. VULNERABILITY

There are different ways of understanding the meaning of the term vulnerability. The one generally accepted is that vulnerability can be defined as the extent to which a society, structure, service or geographical area may submit a hazard on account of its nature and structure, and the distance from areas prone to hazardous events. Vulnerability is a dynamic, inherent characteristic of each community (or household, region, state, infrastructure, or another risk element), which contains a multitude of components [2]. Its scale is determined by the seriousness of the event. Vulnerability points to potential damage and it is a variable that is directed forward or as described by Canon (2008) [3] "vulnerability (as opposed to poverty, which is a measure of the current condition) should involve a predicative quality: it should be a way to imagine what could happen to a certain population in case of a certain risk and danger. To determine the vulnerability means to ask the question what would happen if a certain event (events) affected certain elements that are at risk (eg. society). Vulnerability is a characteristic feature of a community that is always present, even in a quiet period between events. It does not turn on or off as an event does or does not happen. It is a permanent and dynamic property that manifests in the course of events to a certain extent depending on the severity of adverse events. This means that vulnerability can often be measured only indirectly and retrospectively. The measure taken for this kind of indirect measurement is damage caused or general evil. What is often seen as the consequence of a disaster is not vulnerability itself, but the caused damage. Looking at the damage pattern of a society without knowing the magnitude of events beforehand does not permit conclusions regarding the vulnerability of the society. In this regard, the connection strength / damage reflects the vulnerability of the affected element (community, household, nation, infrastructure, etc.). Vulnerability is constantly changing in time and is usually under the influence of an adverse event. It may either increase or decrease depending on that influence. For example, if the poverty rate has increased because of an adverse event, the next event with similar consequences will have a more devastating effect on the impoverished community.



Graph 1. Vulnerability damage - intensity relation.

However, an event that has a small effect can raise community awareness and thus reduce its vulnerability. Vulnerability is a function of sensitivity and adaptability of the system (community, household, buildings, infrastructure, nation, etc.). It is independent of any particular strength of a natural event, but dependent on the context which it occurs in. Vulnerability cannot be estimated in absolute terms. The way of constructing an urban place should be assessed with reference to specific spatial and temporal scales. For practical reasons, the analysis of vulnerability will limit to a specific scenario to be analysed, such as magnitude of events. This is usually the appropriate approach for assessing vulnerability, but the choice of scenarios is subjective. Vulnerability has many dimensions - physical (the way surrounding premises are built), social, economic, that of environmental factors, institutional and human. Most of them cannot be easily quantified. The complexity of vulnerability is determined not only by its many dimensions, but also by the fact that it is dependent on location and that its parameters vary with geographic parameters. The parameters that determine vulnerability are different for the level of households, communities and countries. On the household level the economic dimension parameters such as the amount and diversity of each individual's income are relevant, while at the country level, inflation and gross domestic product are more suitable. From the optimistic point of view, any vulnerability analysis requires adaptation to specific tasks and standards. Professionals in this field must be aware that there are different answers to questions about vulnerability. One possible answer to the question of vulnerability is given in the book by Birkman (2004) [4]. It defines vulnerability in a more complete way including exposure and persistence of the community.

Assessment of vulnerability is performed at the level of a household, group of people, community or country in relation to different types of hazardous phenomena. Once the vulnerability is assessed, standards, regulations and programmes to raise awareness need to be determined with the ultimate goal to reduce existing vulnerabilities and minimize their future appearance. A typical example of this can be determining and binding application of building regulations during object construction. This accounts for towns or cities less vulnerable to hazards such as earthquakes or landslides. These regulations aim to promote sustainable development.

Various activities and professions, and different institutions define vulnerability in different ways. This has resulted in their frequent contradictions. On the other hand, the number of methods for assessing vulnerability is small. Some sociologists even go so far as to argue that vulnerability cannot be measured, but can only be indirectly expressed. In most cases, researchers worldwide are working on developing and testing methods for assessing vulnerability.

In the context of global changes Polsky (2003) [5], the Belfer Centre for Science and International Affairs of Harvard University proposed the assessment of vulnerability in eight steps, and they are:

- define the area of interest,
- understand the research field and its contents,
- find out who is vulnerable in relation to what,
- develop a causal model of vulnerability,
- find indicators that will be the components of vulnerability,
- determine the weighting factors and combine indicators,
- assess future vulnerability,
- publish the results.

Vulnerability assessment usually begins with the historical analysis of events with catastrophic consequences. The vulnerability conditions are identified and systematised from the data on damage and losses suffered by the community. In this framework, civil engineers are mainly engaged. They participate not only in damage assessment and understanding of vulnerability, but also in the process of finding new materials and construction methods to reduce vulnerability.

2.1 Vulnerability indexing: features

From the viewpoint of designers determining and applying indicators and indices allows them to measure and determine the status of a particular community or society which enables them to compare it. It also enables them to identify important parameters that should be pointed out. All this is being done with the aim of promoting a particular direction of sustainable development. For example, measuring the gross domestic product allows comparison between countries within the region. It also allows time to be considered when assessing the dynamics of macro-economic situation during the several years time span. In addition, the development goals can be set up by promoting certain regulations and measures which will change the strength of these indicators in a given direction (increase, decrease). A typical example of such legislation is imposing limits on the concentration of toxic gases in the atmosphere and the related regulations to reduce such pollution. The three most important aspects of these indicators are their internal characteristics, methodologies and data management processes for each of them, as well as availability of information about them. Designing indicators is determined by the way they will be used. For example, in the sector of environment protection indicators are used for monitoring the environment and to track the performance of the measures to reduce the negative effects on the environment. Group for environment of the Organization for Economic Cooperation and Development (OECD) has adopted an approximate set of indicators relating to environment management and sustainability. Its frame is known as the PSR model (Pressure-State-Response).

Pressure indicators describe those variables which directly cause problems in the environment, such as pollution emissions. State indicators reflect current conditions (state) in the environment, such as the concentration of NO_2 in the urban environment, the current concentration of CO_2. Reaction or response indicators demonstrate the efforts of the society to manage these problems. Examples include introduction of cars with catalytic converters, use of unleaded petrol, investing in solar energy and renewable resources. These frames are implicitly related to the vulnerability of the environment due to human activity. They represent the environment state at a moment, but do not determine explicitly what makes it vulnerable. Regardless of that, the frames include reaction indicators which represent activities undertaken to reduce the pressure on the environment by human activities. Maclaren (1996) [6] proposed a slightly different way of developing vulnerability indicators. According to this approach, indicators are developed to monitor progress regarding specific goals. The process begins by identifying and defining objectives for which indicators are needed. The following stages in development of indicators are:

1. Search that can be done by analyzing the target groups for specific indicators, their needs, perceptions and capacity to understand and interpret the results. The search result should be determining the number of indicators to be applied and the space-time distribution of indicators; appropriate indicator framework choice. Possible frameworks include the domain (environment, economy, society), goals (basic needs, economic development) sectors (housing, health, education); problems (industrial pollution, unemployment);
2. Selection criteria with regard to validity, reliability, ease of calculation, accuracy and cost-effectiveness in collecting and processing data; identification of possible indicators in the framework and criteria
3. Selection of the final set of indicators;
4. Assessment of performance of selected indicators in relation to previously established criteria.

Typical characteristics of indicators are interpreted differently by different authors. Hahn (2003) [7] proposed the following characteristics of the indicator:

- Validity: is the indicator the real measure of the element under consideration?
- Sensitivity: if the result changes, will the indicator be sensitive to it?
- Availability: will data acquisition and measurement be easy?

- Objectivity: will the data be reproducible under changed circumstances?

2.2 Vulnerability assessment

The European macro-seismic scale(EMS-98), which was established by Grintal (Grünthal) (1998) [8] and other members of the European Commission for Seismology in 1998, recognises six classes of vulnerability related to different types of construction materials and techniques. It even estimates the expected damage to buildings of each vulnerability class depending on the earthquake intensity. For example, houses built mainly of bricks belong to the vulnerability class A. However, some houses made of bricks can also be classified as the vulnerability class B, as shown in Figure 1. Such homes are expected to experience minor damage (equal to degree 1) in the case of earthquakes with the magnitude V, considerable to severe damage in the case of earthquakes of intensity VII. They are expected to be destroyed when earthquakes reach the intensity IX. According to this scale, the danger is associated with the intensity of the earthquake. While the scale is developed by the systematic analysis of historical damage, it is currently being tested in an attempt to show the expected degree of damage, the scale EMS-98(European macro-seismic scale) is set to 5 degrees of damage:

1 - negligible to light damage;
2 - moderate damage;
3 - significant to severe damage;
4 - very severe damage;
5 - destruction.

The scale of 12 degrees which vulnerability classes are based on spans from those that is almost unnoticeable (volume I) to total destruction (XII volume). Figure 1 describes the way most buildings in the six different classes of vulnerabilities experience damage according to the proposed scale of 5 degrees of damage. As opposed to the EMS-98 (European macro-seismic scale) scale, which focuses on a particular structural vulnerability of buildings and structures, this one takes a fresh approach. Some recent efforts at assessing vulnerabilities have been made in order to compare degrees of vulnerability of countries. Focusing on comparing countries imposed the prerequisite for accessing data of this scale. It led to the use of general indices, such as Gross Domestic Product (GDP), Human Development Index (HDI), degrees of losses to human lives and economic impacts, and some special indices. The next chapter covers the aspects related to system parameters and indices that are needed as a tool for assessing vulnerability.

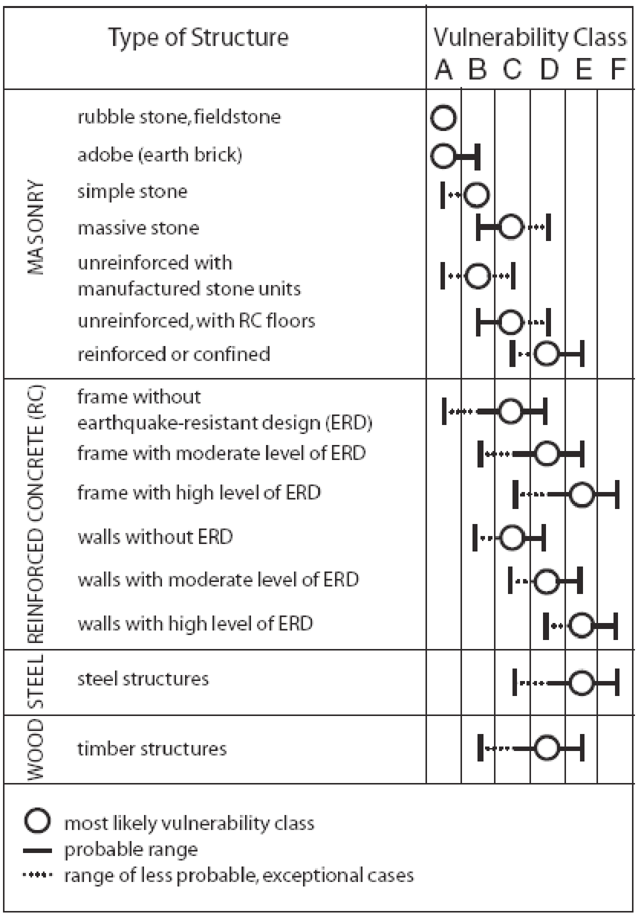


Figure 1. Classes of vulnerability related to different types of construction materials [8]

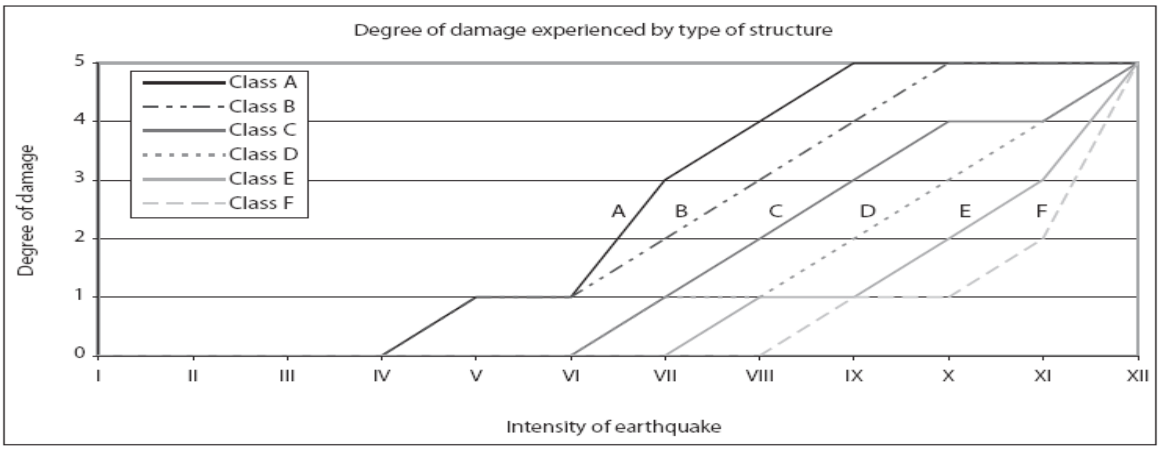


Figure 2. The degree of damage experienced by type of structure

2.3 **Calculating the vulnerability index**

UNDP-BCPR has developed an index of human vulnerability and risk based on human exposure to earthquakes, tropical cyclones, droughts and floods. Relative human vulnerability of a country of a given hazard in this approach is calculated by dividing the average number of people killed per year by the number of people exposed to a given risk. The mean value is obtained from data collected over the period of more than two decades and is based on a database OFDA-CRED EM-DAT. In most cases, calculations are performed with data that span from 1980. to 2000, as this part of the database is considered the most reliable. The number of people exposed to a given risk is calculated by forming the area affected by historical event within the specified time frame. The process involves not only the affected area and a sample of the population living in the area, but also events of different strengths that are included in the database.

For example, the relative index of human vulnerability associated with tropical cyclones is in the range of 0.0 to 321.38 arbitrary units, the floods from 0.0 to 491.84 arbitrary units and the earthquakes of 0.0 to 7652.82 arbitrary units. Taking into account the index as defined by the people who died compared to people who have been exposed, the results can be concluded that human vulnerability to earthquakes is significantly higher than the human vulnerability to floods and cyclones. It can be concluded that the collapse of infrastructure is an important factor that must be taken into account when analyzing human vulnerability to different types of emergencies. Figure 2 shows the results for example of countries in relation to tropical cyclones. The vertical axis is represented on the logarithmical scale, so that the figure shows the behaviour of all countries in the sample. The main conclusions from this approach can be summarized as follows: the index is calculated for 249 countries and three dangers. Threats were selected taking into account two problems: the number of victims related to such hazards and availability of quality data. In the event of an earthquake Armenia, Iran, Yemen and Turkey lead the list of highly vulnerable countries. They are followed by India, Italy, Russian Federation, Algeria and Mexico. As you would expect, these countries have experienced recent earthquakes that caused disasters. It is interesting that Japan and the United States, which have recently experienced earthquakes, show a very low vulnerability, because the relationship between victims and the exposed population is very small. However, Guatemala is presented as a country with low vulnerability, even though it suffered a major earthquake in 1976, outside the time frame established for the calculation.

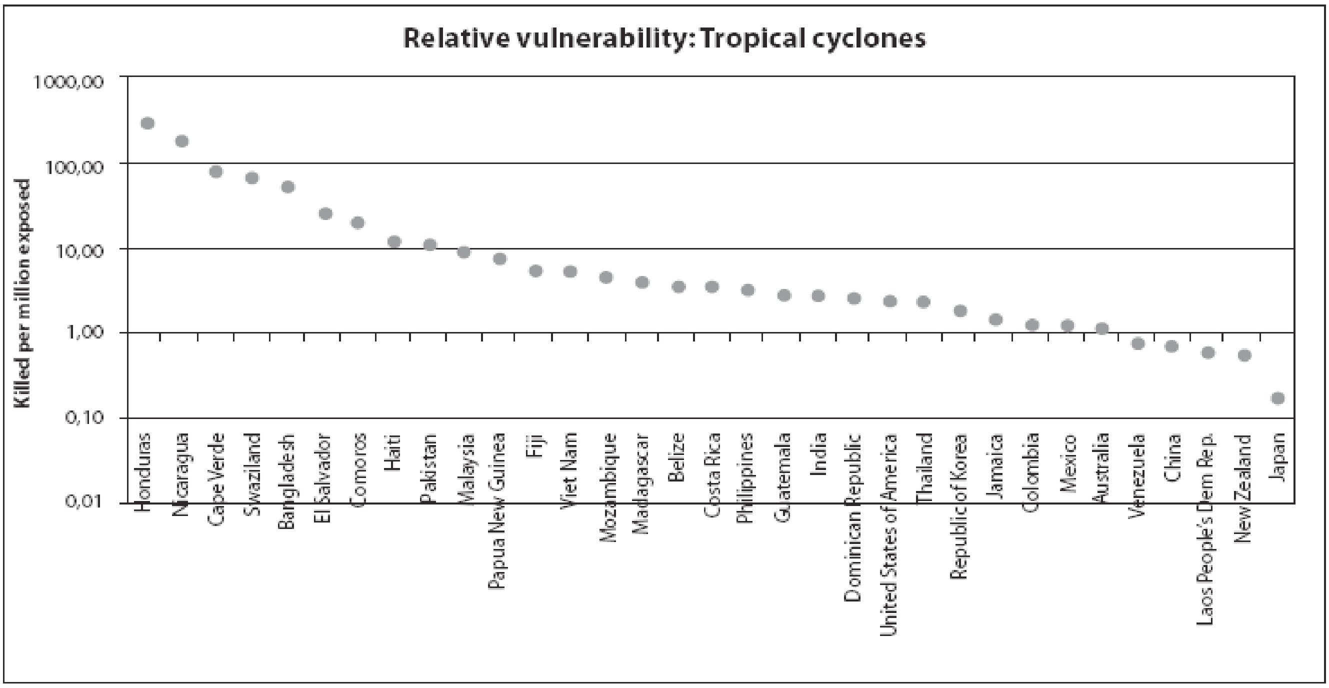


Figure 3. Relative vulnerability of countries to tropical cyclones, as estimated BCPR

In the case of floods Venezuela, Somalia, Djibouti and Morocco lead the list of highly vulnerable countries. Mozambique, for their great flood in 2000, is located in the 10th place on the list. Honduras is in the 21st place, despite the annual floods on the north coast and catastrophic losses during the hurricane Mitch. Haiti occupies the 82nd place, in spite of the great disasters related to floods in 2004. As the case is with the earthquake in Guatemala, the results for floods come out of the time frame selected for evaluation. In the case of tropical cyclones, Honduras, Nicaragua, Cape Verde and Swaziland take up the first places of the list, followed by Bangladesh, El Salvador, Comoros and Haiti. In connection with the methods, the following can be explained:

This index is very clear in keeping the "historical" human vulnerability in relation to different kinds of danger. It is based on deaths directly related to all forms of danger. The calculus is simple and requires historical data on victims, loss or damage in order to calculate an index that can be found from various sources. This index is an index set in relation to mortality. As the authors have presented, the choice is primarily driven by the availability of global data of appropriate quality. Different methodologies can be adopted for determining different social groups (children, women and elderly) and for different geographic levels from national to local. Nevertheless, the data related to mortality in such categories are not available, so the calculus cannot be carried out for all countries at this time.

The index is calculated using the OFDA-CRED EM-DAT database which is being kept updated at all times together with national agencies. Thus, the index can be reevaluated annually. This feature can be used for observing development of vulnerability and risk as a function of time in a relatively simple way, since the data are readily available.

The interval of calculation can be a subject to discuss in the sense that the indices are sensitive only to the events presented in the period used to calculus (1980-2000). Larger events that occurred outside this time frame were not taken into consideration and such events can significantly change the value of the indicator.

The indicator is calculated independently for each form of threat separately. Therefore, it assumes that the vulnerability is dependent on risks.

The value that is created by calculating the relative vulnerability is presented in arbitrary units. That should be taken into account when comparing size indices for different countries. Interesting interpretation in connection with this method and its results is the way to understand them. It is particularly interesting how to understand those developing countries that demonstrate the vulnerability of low value. The case may be that they may refuse any international technical and financial assistance on the grounds of their classification as slightly vulnerable.

Vincent (2004) [9] defined the social vulnerability index (SVI) - IDR to African nations, in relation to risk, defined as changes in water availability. In this sense, vulnerability means the ability of a country to anticipate, resist, defeat and respond to this threat. IDR (SVI) was made based on five indicators:

- Economic prosperity and stability, which was presented to the living standards / poverty and changes in urban population;
- Demographic structure, which was estimated according to the population and the ratio of working population with hiv / aids;
- Institution stability and the strength of public infrastructure, measured as a proportion of gdp invested in health, the number of phones per thousand people and the index of corruption (available only in some countries);
- Global interconnectivity, presented by the country's foreign trade balance; and
- Natural resources dependence, estimated by the percentage of rural population in the country.

IDR (SVI) is calculated by a simple equation:

$$SVI = 0{,}2Iewb + 0{,}2Ids + 0{,}4Iis + 0{,}1Igi + 0{,}1Inrd \quad (1)$$

where:

Iewb - indicator of the economic well-being,
Ids - an indicator of the demographic structure,
Iis - indicator of institutions stability,
Igi - indicators of global interconnectedness,
Inrd - indicator of natural resources dependence.

Each indicator was assigned to its weight through the suggestions proposed by the Expert Group. Most of the data obtained from international sources such as the World Bank, UN agencies, the International Telecommunications Union, Transparency International. Results for 50 countries are represented in Figure 4 they can be briefly presented as follows:

- Niger, Sierra Leone, Burundi and Madagascar lead the list, while Djibouti, Mauritius, Algeria, Tunisia and South Africa are countries that shows the least social vulnerability.
- There is no geographic trends related to the vulnerability of African countries. The least vulnerable countries are on the south and north of the continent.

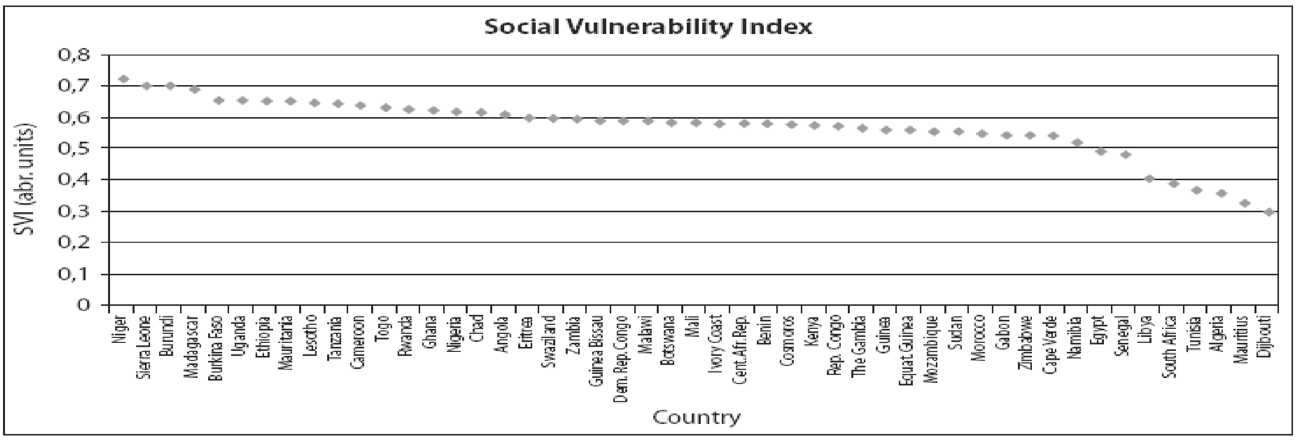


Figure 4. Social Vulnerability Index for African countries as proposed by Vincent (2004)

3. DETERMINATION OF THE STRUCTURAL VULNERABILITY OF FLOODS, THE REVIEW

In the method we present, each type of vulnerability is measured through the parameters that are directly related to the type of vulnerabilities in question, it classify different types of options, generally available in communities for this variable in three ranges: low, medium and high. For flood example, structural vulnerability of the house (residential building) is analyzed true six parameters: the wall, foundation, first floor height, number of floors, windows, doors. Classification of materials was based on analysis of the most commonly used material in a particular area in the past and the present. We need to know some characteristics of this model that could be applied:

- In this model, physical or structural vulnerability is expressed by the current condition of the house and address all elements that can lead to damage or destruction in the event of flooding.
- The method is suited for all hazards. Adaptation to different hazards is possible only through the recognition of hazard impacts on different components of the house.
- Indicators show the vulnerability of households in six types of vulnerability. Different options can be classified with greater or lesser degree of vulnerability, and value can be calculated according to the given weights for each parameter.
- Indicators do not show how vulnerability depends on the intensity of hazard. The method is based on the assumption of high intensity events, and can not be used for events of low intensity.
- Vulnerability assessments can be used for a specific house, and also for the community, municipality, province and national level.
- The method is adapted to building materials which are used in a given region. For each application in other regions must be taken of the building materials used in these regions.
- Method requires specific research at the household level in order to obtain information on six types of vulnerability for each house.

Table 1. Matrix for assessment of structural vulnerability in the flood [10]

	Rating G	Low	Medium	High
Indicators I	WEIGHT	1	3	5
Walls	15	bricks (mortar as a bonding material), blocks (made of brick and concrete), stone	siporeks, durisol, brick with mud as a binding material	adobe-mud, wood
Foundation	10	concrete (reinforced and charged), stone	brick	slag (mixed cements and ash)
Height of the first floor	5	more than 100 cm	from 50 to 100 cm	to 50 cm and below street level
Floors	5	1st floor without basement	1 floor with basement, 2 floors without basement	2 floors with basement, 3 floors with and without basement
Doors	1	no glass	with small glass openings	with large glass openings
Windows	1	smaller windows (small glass area)	medium-sized windows	large windows (the large glass area)

$$V_{vulnerability} = \sum_{i=1}^{n}\sum_{j=1}^{m} I_i G_j \quad (2)$$

where:

I - Indicators
G - Weight

Table 2. The degree of structural vulnerability

The degree of structural vulnerability	Numerical range
Low	37-80 points
Middle	81-130 points
High	131-185 points

3.1 **Walls**

Material for making walls and columns can be natural or artificial origin. Which kind of materials will be used for walls depends on: purpose of the facility, structural system, climatic regions, financial resources and materials that are available in the sarounding.
For creation of walls and pillars are used natural materials: stone, wood, metal, and prefabricats: brick (brick) and clay products, followed by concrete and reinforced concrete, the walls and plaster, cork, glass and synthetic mass. Wall mass can be all of one kind or in combination of two or more types of material, arranged in several layers, and then called multilayer walls. The combination of two layers of the same or different material with a core of insulating material called sandwich walls.

Walls can be made of:

- Brick (brick) can be: solid or hollow;
- Blocks - which may include: brick, concrete and *lightweight blocks of inorganic and organic materials;
- Stone - who may be: broken, an ordinary broken stone, plate and crushed stone, sleek broken stone, crushed stone, stone work, poluklesani, trimmed or carved and specially processed stone;
- Mixed walls - a combination of stone and concrete;
- Wood - who may be: from logs and hewn beams, and
- Concrete - reinforced or nonreinforced concrete.

* Durisol the lightweight concrete with aggregate of small wood debris. They are lightweight, not rot, can not be attack by insects, are resistant to moisture, non-flammable and good sound and heat insulators. As material is processed as a tree .* Siporeks. The main components of this material are quartz sand, cement, water and aluminum powder, which separates the mixture of hydrogen, to form a uniformly distributed pores, which later fill with air, thus achieving the reduction of gravity. The essential difference is between the walls that were built with plaster as a binding material and with mud as a binder. First mentioned walls have the lowest grade and the second have high grade.

3.2 **Foundation**

Selection of materials for the foundations depends on the construction of the building, construction systems, disposable materials and finances. The foundation is second indicator because it represents basis of the residential building.

Materials that can be used for the foundations are:

- bricks;
- stone and
- charged and reinforced concrete.

3.3 **First floor height**

Height of the first floor in relation to the street is different from house to house. If the home base is at a height of 100cm or greater it is least vulnerable since it is unlikely to exceed the amount of ground water (of course all depends on the height of flood waters and terrain). Medium vulnerability is a level of 50cm to 100cm, and the highest rating is given to the house, whose first-floor level is lower than 50cm and below street level and it is considered as the most vulnerable.

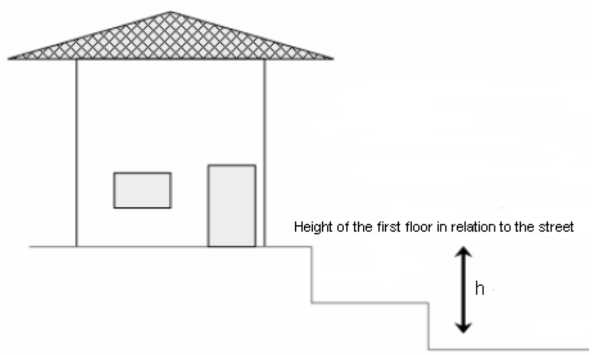


Figure 5. The height of the first floor in relation to the street

3.4 **Number of floors**

Number of floors is indicator because it is assumed that the houses with two floors are more vulnerable than those with one floor. Also the house with basement is structurally more vulnerable than house with no basement. This was concluded based on the assumption that there will be a settlement of land and the foundation of the house, in case of flooding, which can cause damage. So is taken into account that if the house has several floors, this is heavier and is more pressure to the surface. If the house has a basement, in case of floods, its base will be undermined by the influence of water on the structure of the basement.

3.5 **Windows and doors**

In the case of the windows following order was taken. The lowest rating is given for small windows based on the assumption that they will not come near to breaking due to the small glass. They are also easier to replace in case of damage. The mean rating given to medium-sized windows, and most are given for large windows, large glass breaks easily due to water pressure. The materials of which they made the windows were not taken into account because it was thought that among them there is no difference in the effect of water in a structural sense. Everything is the same in the case of the door. The lowest rating is given to doors without glass openings, and the biggest ones that have large glass areas. The assumption is that the door of wood and metal without glasses most resistant to the pressure of flood water.

4. CONCLUSIONS

Analysis of vulnerability progression helps to examine sensitivity of human-environment systems (such as a river or a coastal town) to a variety of social and environmental changes, and their ability to adapt to such changes. Therefore, vulnerability assessment includes perception of exposure, sensitivity and resilience to multiple pressures. The existing vulnerability assessment method and alleviating disaster consequences is a useful tool in analysing progress of vulnerability to floods. For decades, disaster risk assessment in Serbia was based on hazard assessment only. It is difficult to influence on hazard events. Through this research has shown, that the reduction in risk may be affected the most by reducing vulnerability. It is also useful in case of other disasters. It can be seen and concluded how the socio-economic component of disaster affects progression of population vulnerability. This kind of thinking along with alleviating identified pressures creating population vulnerability (root causes, dynamic pressures and conditions of uncertainty) contributes real disaster risk reduction and efficient disaster risk management cycle. Further research should focus on improving the selection of indicators and development models which are estimated in order to obtain a more accurate assessment of vulnerability in disaster risk reduction.

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