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VULNERABILITY ASSESSMENT FOR THE NEAR-EARTH OBJECT IMPACT SCENARIO

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ABSTRACT

The task of this paper is to present two vulnerability assessment methodologies: CIMDEN 2001 structural vulnerability assessment and PAR (Pressure and Release) model which can be used for the hazards produced by Near-Earth Object Impact scenarios.

Vulnerability can be described as “the incapacity of a community to absorb, via auto-adjustments, the impacts of a change in the environment”. In other words, its incapacity to adapt to such a change. Vulnerability assessment addressing the social, economic, environmental and institutional aspects occupies the central part within the research and human capacity building. There are several types of dimensions of vulnerability: physical, environmental, economic, social, political, technical, ideological, ecological, institutional, educational, health-related, cultural, etc. [1]

The Near-Earth Object Impact Scenarios (listed below) influences all the various dimensions of vulnerability mentioned above. [2]

Near-Earth Object Impact Scenarios:
- airburst (an explosion near the atmosphere)
- surface impact

They produce the following hazards which affects the well-being of humans:
- shock wave (overpressure shock) and a blast of wind
- thermal radiation
- tsunamis
- flying debris (ejecta deposition)
- seismic shaking
- cratering

IMPACT HAZARDS

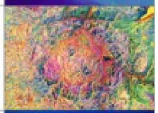
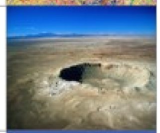
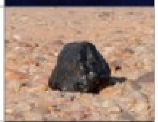
DIAMETER OF THE IMPACTOR	EVENT TYPE	EFFECT	ENERGY (MT = Megatons TNT)	TIMESCALE (years)	EXAMPLES	NOTES	CREDITS ESA / NEOCC
>1 km	**Impact**	Global (climate change)	> 100.000 MT	> 1 million	- **Chicxulub**	Chicxulub is a 170-km crater whose formation is thought to be responsible for the Cretaceous / Tertiary mass extinction (K/T boundary).	
150 m	**Impact**	Local (earthquakes, tsunamis)	100 MT	~ 10000	- **Iso Naakkima** - **Zhamanshin**	Craters of the order of 10 km can be considered as limiting cases between local and global consequences.	
50 m	**Impact**	Local (earthquakes, storms)	1 MT	~ 1000	- **Tunguska** - **Meteor Crater**	Outcome depends on the impactor composition and dynamics. Tunguska was a large airburst producing no crater. The Meteor Crater was formed by a metallic impactor.	
10 m	**Impact / Superbolide**	Local (craters, blast waves)	< 1 MT	~ 10	- **Kamil** - **Carancas** - **Chelyabinsk**	Carancas was a slow high altitude event producing a 12 m crater. The Kamil crater (40 m diameter) was caused by a 1 m iron impactor. The Chelyabinsk event resulted in an object which fragmented completely before reaching the ground.	
1 m	**Bolide**	Local (local flash, meteorites)	10 kT	~ 1	- **Revelstoke** - **2008 TC3**	The Revelstoke fireball led to the recovery of meteorite grains. 2008 TC3 was the first meteorite fall observed prior to atmospheric entry.	
1 cm <	**Meteor**	Upper atmosphere / near-Earth environment (shooting stars, Spacecraft damage)	Negligible	Hourly rates	- **Perseids** - **Leonids** - **Geminids** ...	Sporadic meteors and meteor showers (shooting stars) can be of cometary or asteroid origin. Since these bodies completely burn in the upper atmosphere, damages are limited to orbiting infrastructures.	

Figure 1. summarizes present knowledge of the impact hazard, including the frequency of occurrence of selected events and their consequences [3].

Example: Case study of an impact - Barringer Meteor Crater

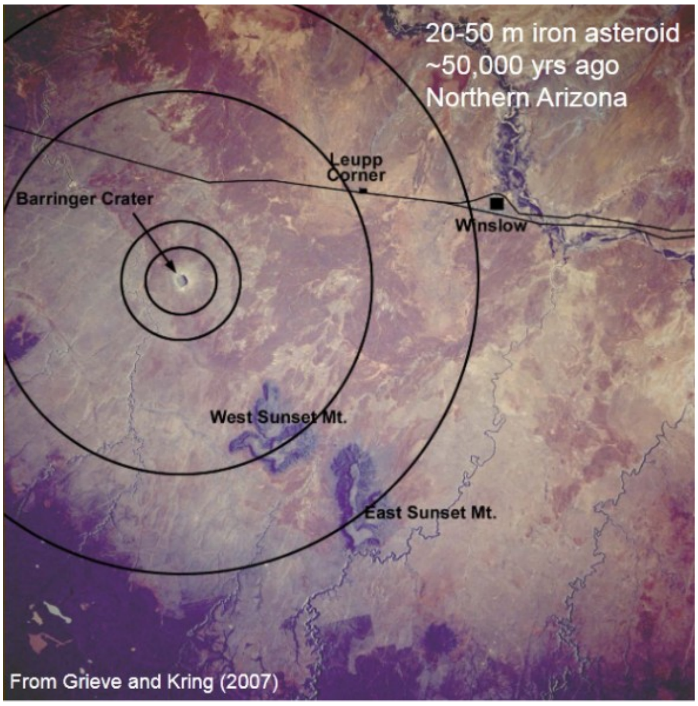


Figure 2. Example: Case study of an impact - Barringer Meteor Crater [4].

- In small events, the fireball, shock wave and blast of wind are the major environmental effects.

- The blast effect was immediately lethal for human-sized animals within the inner 6 km diameter circle.

- Severe lung damage would occur within the next 10-12 km diameter circle due to the pressure pulse alone and animals would be severely injured and unlikely to survive.

- Winds would exceed 1500 km/hr within the inner circle and still exceed 100 km/hr at radial distances of 25 km (third circle).

- The outermost ~50 km circle represents the outer limit of severe to moderate damage to trees and human-structures of comparable strength.

METHODOLOGIES

Household Sector Approach: CIMDEN 2001

In a different approach, the author has developed a procedure to assess four different types of vulnerabilities associated with the housing sector at the local level: physical or structural, functional, social, and economic income. In this method, each type of vulnerability is measured through parameters which are directly related to the type of vulnerability in question, classifying the different types of options commonly available in communities for these variables in three ranges: low, medium and high. The overall vulnerability is presented in terms of arbitrary units and classified in three ranges according to a pre-defined table. In this case, it is important to recognize several aspects: [1]

In this model, physical or structural vulnerability is expressed according the present condition of the house and addresses those elements which can lead to damages or destruction in case of an event. The method has been adapted to handle different hazards. Adaptation to different hazards is made recognizing the impact of the hazard on the various components of the house.

The indicators display in an explicit or direct fashion the vulnerability of the household through the four types of vulnerabilities. It assumes that different options can be classified with higher or lower degrees of vulnerabilities, and computes a value according to the assigned weights to each parameter considered.

The indicators do not show how vulnerability depends on the magnitude of the hazard.The method is based on the consideration of a very high magnitude event, but cannot cope with small-magnitude events.

The vulnerability assessment can be employed to assess the vulnerability of a single house, but can be aggregated at the community, municipal, province, and national level. Figure 4. displays the assessment of structural vulnerability for flood event. Houses have been classified and identified as low vulnerable (green), medium vulnerable (yellow) and highly vulnerable (red).

The method identifies options to reduce the degree of vulnerabilities explicitly, but has been constructed for specific regions of the world (construction materials and construction techniques present in one region of the world for example). Its extrapolation to other regions of the world will need adaptation.

The method requires a specific survey at the household level to gather information on the four types of vulnerabilities within the housing sector for each house.

		LOW	MEDIUM	HIGH
	WEIGHT	1	3	5
Walls	15	bricks (mortar as a binding material), blocks (made of brick and concrete), stone	siporex, durisol, bricks with mud as a binding material	adobe-mud, wood
Foundations	10	concrete (regular and reinforced), stone	bricks (mortar as a binding material)	the mixture of bottom ash, water and cement
Height of the first floor	5	more than 100 cm from the street level	from 50 to 100 cm from the street level	to 50 cm and below street level
Number of floors	5	first floor without a basement	first floor with a basement, two floors without a basement	two floors with a basement, three floors with and without a basement
Doors	1	without glass	with small glass area	with large glass area
Windows	1	small windows (small glass area)	medium sized windows	large windows (large glass area)

$V_{estruct} = 15 \times 3 + 10 \times 5 + 5 \times 5 + 5 \times 1 + 1 \times 3 + 1 \times 1$

$= 129$ medium degree of structural vulnerability

Degree of structural vulnerability	Numerical range
Low	37-80 points
Medium	81-130 points
High	131-185 points

Figure 3. Example of adapted Flood Structure Vulnerability Assessment. Important: building materials depend on the region of interest. [6]

Figure 4. Structural vulnerability of individual houses with an assigned color (degree of structural vulnerability) overlapped with simulated flooded area based on DEM and historical disaster database. [6]

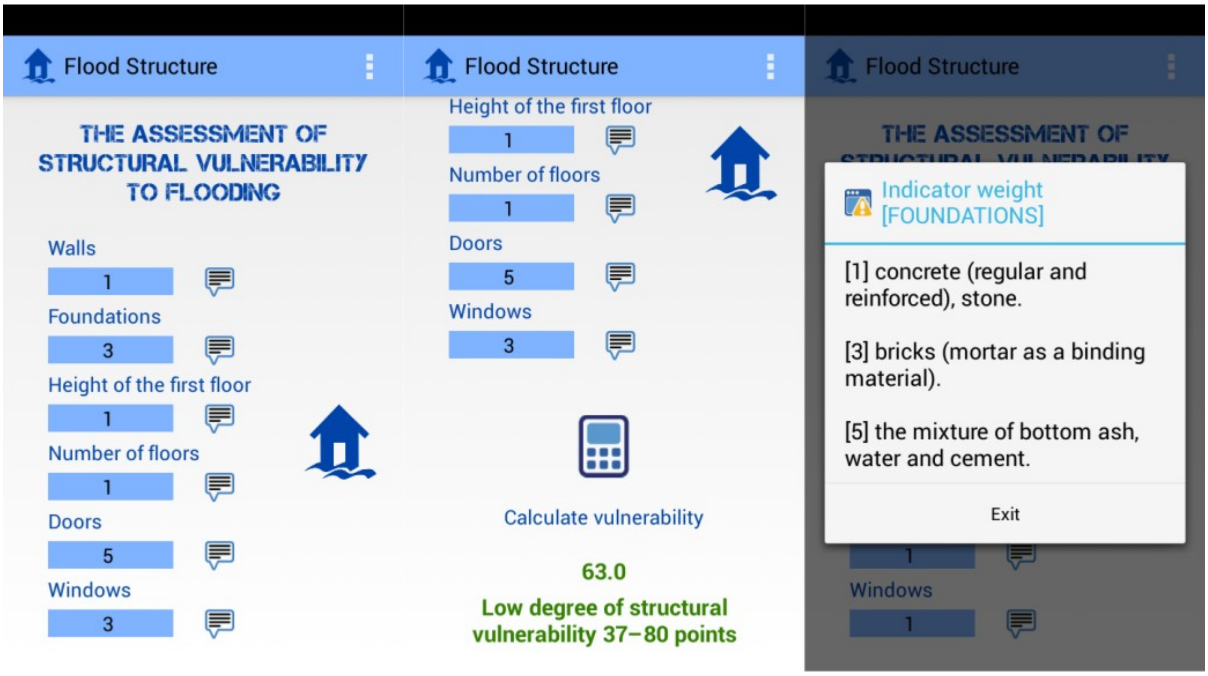


Figure 5. The Android application for rapid structural vulnerability assessment to floods. It can be adapted to other hazards produced by Near-Earth Object Impact Scenarios. [6]. The source code is available on GitHub. [7]

The Disaster Pressure And Release Model

The Pressure and Release Model - PAR model defines vulnerability as the characteristic of a person or group of persons in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard. In addition, the PAR model describes the progression of vulnerability associated with root causes, dynamic pressures, and unsafe conditions. [5]

- Root causes are associated with economic, demographic, and political processes within a society. These reflect the exercise and distribution of power in a society;
- Dynamic pressures, which channel the root causes into particular forms of unsafe conditions, among them population growth, rapid urbanization, deforestation and decline in soil productivity, as well as the lack of training, appropriate skills, and local conditions of markets and policies;
- Unsafe conditions, which are manifestations of vulnerability in time and space in conjunction with the hazard in such issues as fragile local economy, lack of disaster planning and preparedness, and fragile environment.

The strength of this approach resides on its capacity not only to define vulnerability, but to explain its generation as a three step process. [1]

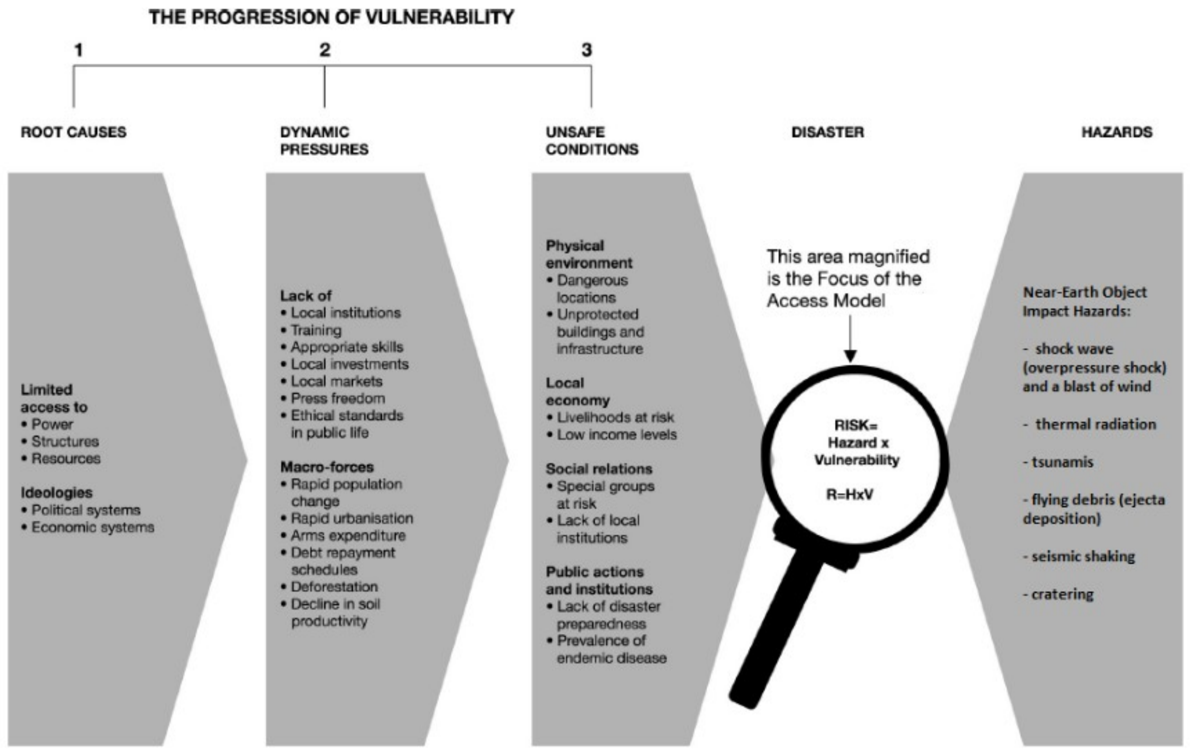


Figure 6. Pressure and Release (PAR) model: the progression of vulnerability with Near-Earth Object Impact hazards. Edited [5]

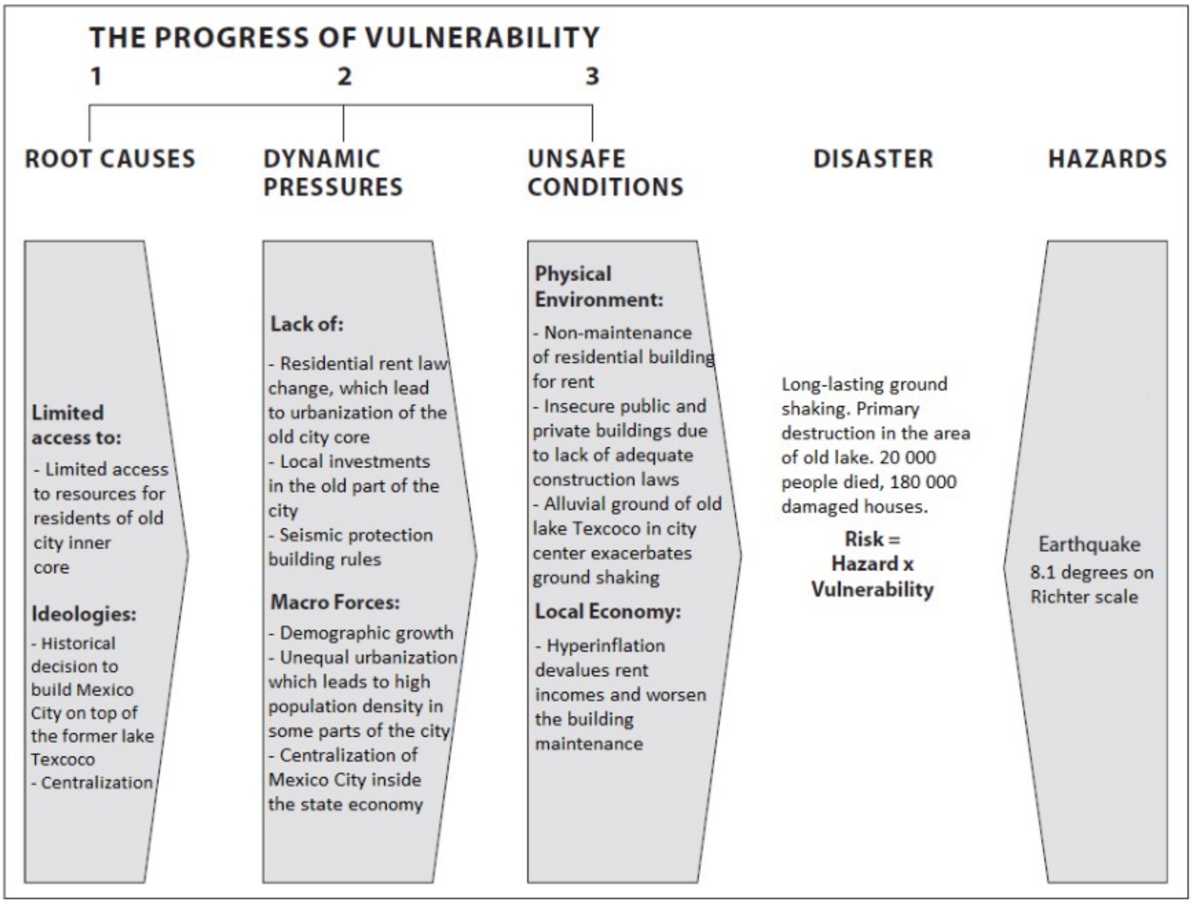


Figure 7. Example of Pressure and Release (PAR) model: the progression of vulnerability in the case of Mexico City Earthquake 19.09.1985. Edited [5]

CONCLUSION

The above two mentioned methodologies are just part of the existing methodologies in vulnerability assessment. Every vulnerability assessment for natural hazards (such as: volcanic eruption, earthquake, storm, tsunami-flooding) can also be used for the Near-Earth Object Impact scenarios which produce similar hazards (blast of wind, tsunami-flooding, thermal radiation, flying debris-ejecta deposition and seismic shaking). Therefore, we present the application of these methodologies in the case of the flooding-tsunami event and earthquake-seismic shaking produced by the NEO surface impact scenario. The main objective was also to get the focus of NEO community to vulnerability assessment as a necessary tool in disaster risk management cycle.

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[7] GitHub Link: https://github.com/jefticRSe86/FloodStructure