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Research Article

THE HIDING VULNERABILITIES OF CITIES CASE OF BOUMERDES DISASTER IN 2003

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ABSTRACT

Actually the hazards are not the direct causes of disaster, the degree of vulnerability of populations to hazards do not depend solely on the proximity of the source of threat or the physical nature of hazard, social factors also plays an important role in determining vulnerability. According to the risk management model, physical and social vulnerability are linked to the place of vulnerability. In this research we explain disparities of losses and damages after the disaster of Boumerdes cities in 2003. We assess the relation between social and physical vulnerabilities and how they built the disaster of 2003. A geographic information system was used to establish areas of vulnerability based upon the expertise of the built environment and 10 social characteristics for the cities of Boumerdes Province.The important result is the intersection of degrees of physical vulnerability with those of social vulnerability; the other result is that the most socially vulnerable cities are those living in areas of high physical vulnerability. This manuscript contributes to the development of a general theory on disasters as an intersection between social and physical vulnerabilities and highlights the importance of integrating vulnerabilities into risk and disaster reduction policies in Algeria.

Keywords: hazard, physical vulnerability, social vulnerability, geography information system, model of risk disaster.

The relation between physical and social vulnerabilities and the management of risk and disaster

The rapid urbanization increases the exposure of world's population in cities to acute shocks and long-term stresses such as floods, earthquakes, climate change or social dynamics. During 2000 and 2010 a several natural events have affected Algerian cities, the 2003 earthquake is the most important, distressing Boumerdes and Algiers, resulting in 2275 deaths, and destroyed 43500 houses. After the disaster, an assessment and expertise of the damage caused to buildings were conducted. Indeed, it is usual that after a disaster these operations are carried out, as the impact evaluation of the seismic hazard on buildings is crucial to estimate the costs and damages, as well as to understand the causes of the disaster. The risk is an assertion that social vulnerability and multiple forms of risk are the root cause of these disasters. It is not only the organizational or system-level technical factors that should be considered when dealing with disasters, but also the social aspects.

The United Nations International Strategy for Disaster Reduction, has defined disaster as the "combination of the exposure to a hazard, the conditions of vulnerability that are present and insufficient capacity or measures to reduce or cope with the potential negative consequences. Disaster impacts may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation." The central concepts and notions are the conditions of exposure, vulnerability and society's ability to cope with them. In addition, these terms appear in the early definitions of vulnerability. Vulnerability is defined as the degree of loss and subsequent damage caused by the hazard, and is measured in terms of real or

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expected damage to the elements exposed to a hazard. Vulnerability here refers, "to exposure to contingencies and stress, and difficulty in coping with them. Vulnerability has thus two sides: an external side of risks, shocks, and stress to which an individual or household is subject; and an internal side which is defencelessness, meaning a lack of means to cope without damaging loss. Loss can take many forms becoming or being physically weaker, economically impoverished, socially dependent, humiliated or psychologically harmed. We should add that vulnerability can also refer to effects on the community. Alexander (1997),defines vulnerability as long-term factors that affect a community's ability to respond to events or make it vulnerable to disasters.

According the risk management model (figure1), physical and social vulnerability are linked to the areas of vulnerability or places of vulnerability. Places or spaces of vulnerability are used to examine some of the social and physical elements at risk and who contribute to vulnerability and to assess their interaction or intersection.

Vulnerability is therefore the central concept for analysing risks and disasters. According to Veyret(2003), the concept of vulnerability, was born from the idea that hazard alone is not sufficient to understand the cause of a disaster. Indeed, a hazard with a lower intensity could have very serious consequences in some societies, while another hazard with a higher intensity could have negligible impacts. A lot of research has examined components of biophysical vulnerability and the vulnerability of the built environment, but currently. Know the least about the social aspects of vulnerability. Social vulnerability is the probability of identifiable persons or groups lacking the "capacity to anticipate, cope with, resist and recover from the impact of a natural hazard".

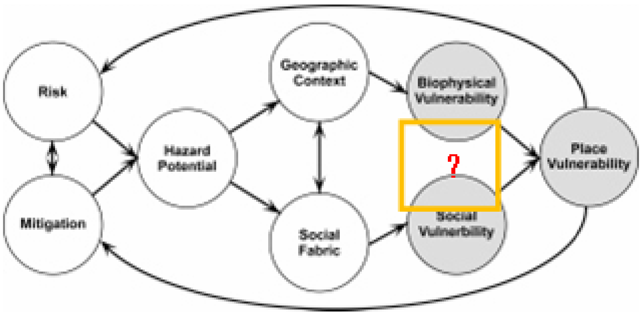

Figure 1 : risk management model (source: Cutter and al. 2000 modified author)

In the Algerian context, the policy of disaster and risk management are particularly focused on the evaluation of physical aspect and the built environment, while the social issues at the root of this vulnerability have been largely ignored and long absent from post-disaster reports. Thus, disaster losses and costs have been quantified, but human and social factors relating to populations have been neglected. This explains why, despite efforts to prevent natural hazards, the number of injuries and property damage has continued to rise. Therefore, it is understood that knowledge of vulnerability can provide a means to contribute to risk, hazard and disaster reduction, taking into account the constructions of risk, exposure, hazard, resilience, sensitivity and recovery.

The scientific objective of our research is to contribute to the development of a general theory on disasters as a social phenomenon and physical vulnerabilities. According to the vulnerability model developed by Cutter (2000), physical and social vulnerabilities are directly related to places or to the urban environment ."Focusing on the urban environment provides an opportunity to examine some of the underlying social and biophysical elements that contribute to vulnerability, as well as to assess their interaction and intersection. Place vulnerability can change over time based on alterations in risk, mitigation, and the variable contexts within which hazards occur".

Levels of vulnerability and exposure help to explain why some hazards that are not extreme can lead to extreme impacts and disasters. In other words, the hazard is the same, but the impacts and losses are different. In order to understand the 2003 seismic disaster in the province of Boumerdes and explain the buildup of the physical vulnerability, as well as the social vulnerability of the inhabitants, we began by analyzing the factors that contributed to the construction of this disaster and the elements that caused these vulnerabilities. Already, we confirmed the hypothesis that the disaster is the fabrication of social and physical vulnerabilities.

Our analysis focused on the damage, in order to provide the response and sensitivity of the materiel objects. There are several issues exposed to hazard, including material issues. They depend on the type of building, i.e. residential, non-residential and various networks. Buildings and urban structures are the first to react to a ground shaking. The data collected after the 2003 post-earthquake expertise analysis enabled us to estimate their sensitivity, degrees of damage, as well as their impacts on society and the population of the Boumerdes Province before and after the seismic event.

Additionally, the prioritization and classification of physical problems by the municipality is important for understanding the collapse of certain buildings based on their exposure and resistance to this hazard and for identifying cities that are physically vulnerable. Physical losses have affected the functions of buildings, as is the case of houses in the province of Boumerdes. The physical vulnerability of buildings directly affects the users of these spaces, as in the case of residential buildings, the inhabitants were directly affected during and after the earthquake.

We assume that the inhabitants made this physical vulnerability before the disaster of 2003. Therefore, the assessment of human vulnerability at the level of each town in Boumerdes province, through human factors, and then through social and economic factors, is necessary to assess the social and human vulnerability of the population of these communities before the 2003 earthquake.The combination of material and human indices confirms the construction of physical vulnerability by the social vulnerability of the populations, and the fabric of the 2003 disaster risk.

ASSESSMENT METHODS AND TOOLS

Vulnerability assessments have become usual with descriptions of procedures, types, methods, and conceptual. There are two types of assessment methods including either qualitative empirical assessments or semi-quantitative, often spatially explicit, place-based approaches.

After the 2003 seismic disaster that struck the province of Boumerdes, an expertise analysis of the damaged buildings was established by the National Centre for Applied Research in Earthquake Engineering. According to an evaluation model called the European Macroseismic Scale (EMS). We analysed these data and classified by degrees and indices of damage with Arcmap logical, the quartile formula was used with the aim of highlighting the most affected municipalities. The residential buildings were severely affected and the degrees of damage varied from one municipality to another. The physical vulnerability depends on three factors: exposure, proximity between a hazard and issues, and the role of proximity in damage mechanisms (Dauphiné and Provitolo 2013).Note that resistance is the possibility of a system to counteract a fracas without suffering damage. The sensitivity of the system is the physical resistance of buildings from which is derived. Therefore, sensitivity is the degree of damage the system can sustain, the greater the losses, the greater the sensitivity, and vice versa.

To explain the disparity of damage between the different Cities of Boumerdes Province, we estimated the fragility internal elements of the buildings through physical factors. Risk of damage dependent on factors of physical vulnerability, such as the type of building, number of floors, building materials, etc. We have selected these factors, the constructive system, the age and the height of the building, to estimate the different degrees of damage. These criteria allowed us to provide answers on the very significant damage rates of buildings.

The first criterion is the typology of the constructive system; this criterion depends on the materials used to build the supporting structure of the building, which is masonry, reinforced concrete or metal structure. In the event of an earthquake, each structure behaved differently. In general, the reinforced concrete structure is more resistant to seismic hazard if it complies with the technical instructions guidelines. Reinforced concrete can present certain defects that remain hidden (faults), as soon as it is shaken by an earthquake, these defects cause accelerated degradation due to the lack of perfect cohesion of the two materials which are concrete and steel reinforcements. In the case of a masonry structure, however, when the latter is subjected to the violent horizontal thrusts of an earthquake, the mortar beds of the masonry wall consequently fail to ensure satisfactory cohesion between the masonry blocks, which then break up. Even for moderate deformations of the wall, the mortar is thus the site of (weakness) ruptures. On another side, the walls cannot be distorted without cracking, which is not the case with reinforced concrete, which is more resistant thanks to its reinforcements.

The second criterion is the age of the construction; it gives an indication of the obsolescence of the buildings with regard to maintenance by the occupants. Poor maintenance of the building makes it more vulnerable to natural hazards. With the age of the building, it is possible to evaluate the consequences of the reference earthquakes during its construction. Before and after 1962, buildings constructed during this period were subject to the rules of the 1956 earthquake code (French code). After 1980, the Algerian Paraseismic Rules of 1988 (RPA1988) were applied and modified in 1999.

The last criterion is the number of stores, losses are more important for a multi-story construction, and it is the low-rise buildings which are better resistant to the earthquake.

The damage on the physical material was very important. This vulnerability has directly influenced the social functions of people's daily lives. There is another element at risk(issue) that has contributed to the increase in casualties. The social vulnerability of populations: "The probability of occurrence of the extreme physical phenomenon is constant. If this probability is constant, the only logical explanation for the increase in disasters must be sought in the increasing vulnerability of populations to extreme physical phenomena".

We thought that before the 2003 earthquake, the populations and society of the province of Boumerdes were vulnerable and they participated fully in the fabric of seismic risk and disaster, as stated by Cutter "Vulnerability is the pre-event, characteristic of social systems that create the potential for a risk or a disaster".

Social vulnerability is more often described using people's individual characteristics (age, race, health, network, type of housing, employment), these factors influence and shape the susceptibility of different groups to harm. They have the effect of hindering or directing their ability to respond. They also indicate where social inequalities crystallize.

Consequently, the assessment of social vulnerability requires the selection of a set of indicators to best characterize it. This is why integrating the social vulnerability of the population into a human risk assessment tool is relevant, since it is one of the factors aggravating the consequences of the hazard.

The method used is based on the exploitation of socio-economic and demographic data in order to construct a social vulnerability index. The factor analysis approach has made it possible to select ten variables (Table 1), which contains non-exhaustive data, shows that certain vulnerability indicators are used in several of the approaches listed. In particular, these are indicators relating to the age of the population (minors and older people), household income (average income, poor people, and households without a car, owner or tenant of the dwelling) or household status (single-married, households). These indicators are relative to social (or socio-economic) vulnerability is independent of hazard. They were placed in an additive model to calculate a summary score of the human and social vulnerability of Boumerdes Cities.

Goals	Features	Variables
Human vulnerability	Population structure : and	Population density ;

	People's physical weakness makes them more likely to be exposed to danger. There is a disparity in access to resources.	Elderly (65 and over) ;
		Children under 5 years old ;
		Gender (female);
		Single-parent households and single people;
		People with disabilities and the long-term ill.
Social vulnerability	Vulnerability of the building	Housing resident ;
		Communal building ;
		Low income home ;
		Low level of education (no study after high school).

Table 1: The criteria of social and human vulnerability (source :Cutter et al.,2000)

The gender (female) and children indicators, we noted that the loss rate was very high (2100 dead). Since the quake struck at 19.44 PM, women were at home at this hour. It is the same for the children, who indeed had finished school for more than 2 hours. This explains the very high loss rates recorded not only among women, but also among children (Figure 2), while these two categories constitute the most fragile social groups.

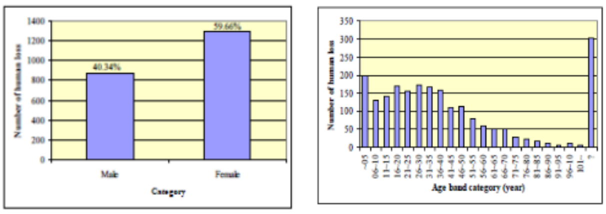

Figure 2: Human losses by gender and distribution age, Boumerdes 2003 (Source: Bechtoula, H.Ousalem, H., 2003)

For the elderly and sick indicators, we have observed that older people (65 years and over) may have difficulty in mobility which slow down their ability to prepare before the disaster, but also to evacuate during the disaster. They will need the help of family members or emergency services to evacuate. On the other hand, for disabled and long-term sick people with reduced mobility, evacuation requires the assistance of several people, whether they are family members or external workers (firefighters, civil safety, etc.). This category has very limited physical capabilities to protect the building and its property from earthquakes, making it more likely to be at risk.

Single persons indicators relate, inter alia, to people living alone and/or with weak family ties, and who therefore find themselves alone during the earthquake. In this regard, our survey in Dellys on 2017 revealed the existence of many one-person households.

For the criteria of social vulnerability, we have chosen the indicators that have a direct relation to the building.

Regarding the indicator, renters, we found that renters and people living free of charge have generally been present in the dwelling for less time than homeowners. As a result, they are less inclined to implement measures to protect or adapt the building, as they feel that the costs of these measures are the responsibility of the owners of the building or dwelling. It is less likely that they will be aware of the natural phenomenon of the earthquake. As a result, they are often less well-prepared.

As for the indicator education, it refers to the fact that the low level of education limits the ability to understand warning information and access to information to prepare and reduce the risk.

For the indicator, income or resources, we noted that low-income households have limited financial resources to implement measures to protect the building and its assets. Their exposure to natural hazards is therefore often higher. In our survey at Dellys 2017, we observed that low-income households were finding it more difficult to find living conditions similar to those before the disaster, because they lacked financial means.

In addition, we used the only detailed data available on the inhabitants of Boumerdes before 2003, which data are from the General Census of Population and Housing (GCPH) conducted in 1998 to estimate these criteria.

BOUMERDES; A PROVINCE WITH MULTIPLE VULNERABILITIES AND MULTI HAZARDS

Occurrence of the Seismic hazard

Risk is an eventuality; a potential harm related to the occurrence of a natural event, one of the components of natural risk is the event of a natural hazard or danger. This hazard is defined in particular by a probability of occurrence. This probability itself depends directly on the history of past events. This is why, it is essential to look back at past earthquakes to understand better this natural phenomenon.

Boumerdes, is a coastal territory of central Algeria, it covers an area of 1,456.16 km2 with a coastline of 100 km, and is located between the Cape of Boudouaou El Bahri in the east of Algiers and the limits of the municipality of Afir west of the provinceof Tizi-ouzou. This locality is also a grouping of 32 municipalities, spread throughout its territory from East to West.

Its natural and physical environment is varied; there are rich and diverse geomorphological assemblages. The geographical originality of this province lies in the fact that it has a diversity of relief types. Thus, in the North, the Mediterranean coastline stretches from Boudouaou El Bahri to Cap Djinet. To the South, the relief is dominated by the foothills of the Atlas Blidéen and the highland of Bouira, where the highest point in the Province culminates at 1031 m at Ammal. While to the west, the Mitidja plain dominates, and to the east, the massif of Upper of Kabylie. These morphological and structural assemblages result from a complex tectonic evolution, namely the convergence of two large continental plates of Africa and Eurasia. The Boumerdes Province being included in the northern part of the Tellian Atlas, it is thus linked with this set to the great Mediterranean Alpine system, where easily erodible rocks predominate.

Quaternary deformations in the Tellian Atlas indicate the existence of folds in a narrow band from east to west. The overlapping of the reverse faults and the associated folds spilled towards the south-east were caused by a compressive deformation linked to these two large plates. The moderate earthquakes at low magnitudes of the Boumerdes Provincewere mainly due to the seismic activity of the Thénia fault, since during history this Province was affected by three important and high intensity events, the earthquake of 2 January 1365 of an intensity (X) which would have destroyed Algiers and generated a small tsunami, a second on February 3, 1716 of an intensity (X), probably again destroying Algiers, latter on October 29, 1989 the earthquake with6.0 magnitude affected the Province of Tipasa(Yelles-Chaouche et al. 2006).

On May 21, 2003, the Provinceof Boumerdes trembled after an earthquake that occurred at 7:44 P.M. and 36 s (6:44 P.M. GMT), its epicenter was at seaabout 7 kilometers north of Zemmouri. The coordinates are 36 ° .91N and 3°.58E, and the focus was located 10 kilometers deep. The magnitude has been estimated at 6.8 on the Richter open scale by the National Center for Research in Astrophysics and Geophysics Algiers (CRAAG).

This intensity was observed and felt in the regions of Boumerdès and Algiers, over an area going mainly from Blida to Dellys, an area of approximately 150 km x 80 km. This earthquake was widely felt in the bordering Provincesof Medea, Tipaza, Bejaïa and Bouira and even in the Balearic Islands in the North, 300 km from the epicenter. This main shock was followed in the following days by hundreds of aftershocks, the strongest reaching a magnitude of 5.8. These are the geophysical elements characterizing this earthquake (Figure 3). However, what about the material and human stakes?

Earthquake impact on the hazard elements

Before 2001, Algeria experienced several natural events, resulting in numerous victims and damage, more than 4,678 deaths, 9,690 injured, 465 missing, 574,450 victims and 30,100 homes damaged. The overall cost of losses has been estimated at 33 billion dinars, the equivalent of $ 2.7 billion (the National Economic and social Council2003)1. But each province affected differently, because the material and human challenges are specific to each region, and the impact of natural events on the territories is not the same. We have identified the hidden stakes that were affected and revealed by the 2003 seismic disaster, which we will present below.

In the evening of the 2003 disaster, a crisis unit was set up in the province of Boumerdes. Indeed, the rescue organization (ORSEC) launched a plan of actions in agreement with the interior ministry of local government. It consisted of the establishment of various crisis management modules, including firstly taking charge of human lives through rescue, and evacuation, then ensuring security and public order. In addition, information, communication, medical care and hospitalization modules, an emergency recovery module for communication networks and other more or less affected basic infrastructures, have been set up. For damaged buildings, an expertise module was put in place to organize the operations of damage assessment that affected the building of the Province of Boumerdes. In the early hours of Thursday, May 22, 2003, the extent of the damage was noted, it was announced 1,391 deaths and 3,444 injured throughout the territory. In addition, an inter departmental decree was promulgated on May 24, 2003 to declare 26 municipalities affected (figure4) out of the 32 municipalities of Boumerdes Province2. The degree of intensity of this seismic was estimated at (X) on the Mercalli scale. This means that the destruction of the constructions was almost total, including those that were of superior quality. Why so much damage? How did the internal factors of this material stakes participate in amassed sensitivity to this seismic hazard?

Figure 3: the effect of the earthquake on Dellys "Lajenna" beach before March 11, 2003 and after the earthquake on June 10, 2003 (Source: Belazougui, 2004)

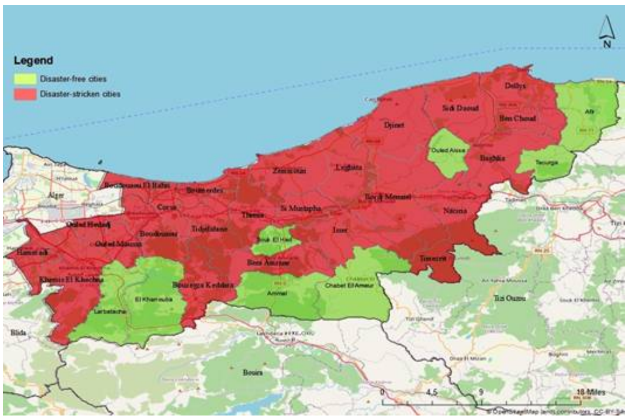

Figure 4: the settled cities order on May 24, after the hazard seismic of May 21, 2003 (Source: author)

ANALYSIS OF THE VULNERABLE FACTORS

At the end of 20022, the Boumerdes Province had 112,643 dwellings spread over 32 municipalities for a population of 710024 inhabitants. The division of crisis management of Boumerdes declared 56,401 dwellings damaged throughout the Province, it is the half of the residential buildings. In addition, significant damage was recorded at the municipalities of Bordj Menail, Dellys, Boudouaou and Boumerdes, which shows that the residential building was indeed fragile. The analysis of statistical data of the damaged buildings is classified by degrees of damage; these degrees are similar to the assessment model called European Macroseismic Scale(EMS).Most of the residential buildings were affected to different degrees and at different indices. The application of the quartile formula has allowed us to highlight the most affected municipalities, which are Boudouaou, Bordj Menail, Dellys, Zemmouri, Cap Djinet, Boumerdes, Beni Omrane and Tidjelabine. The buildings of these cities were certainly more sensitive and vulnerable before the earthquake of May 21, 2003. The seismic event had revealing this physical vulnerability.In addition, we noticed significant rates of damage to residential buildings in municipalities near the epicentral area such as Zemmouri and Bordj Menail. However, this was not necessarily observed after the 2003 earthquake in the most remote municipalities such as Cap Djinet, Boumerdes, Beni Omrane,Tidjelabine, Boudouaou and Dellys. The distance to the epicenter is therefore not the determining criteria explaining the degree of damage from the hazard seismic of 2003; it depends on other criteria (Figures 5 and 6).

To assess the fragility of the buildings, we analyzed the related internal factors. The damage rates were estimated by criteria by using the statistical data of damaged buildings on the total of existing residential buildings at each Citiesof Boumerdes before December 31, 2002. Subsequently, we classified them using an Excel table to assess their vulnerabilities by damage.

The first criteria used to diagnose building damage rates is the typology of the system construction. Thus, we assessed the damage rates by type of structure based on the total number of damaged buildings. It was therefore noted that the sensitivity of each system of construction was different. Reinforced concrete buildings had poor resistance, while masonry buildings withstood the earthquake better, with the exception of those in the cities of Ouled Aissa, Cap Djinet, Dellys, Afir, Souk El Had. These suffered damage to the same degree as the reinforced concrete buildings. This shows that it is necessary to establish analyzes specific to this region. For reinforced concrete buildings, all the municipalities were affected differently. In order to appreciate the quality of these rates, we applied the definition of the EMS 98 of the concepts "a little", "a lot" and "most" in percentage. The rates between 0 and 19% are of the "a little" type, between 20 and 50% the damages are of the "a lot" type, and the rates of more than 51% are of the "most" category.

The results obtained are as follows. Reinforced concrete buildings suffered extensive damage in 19 municipalities, while for 11 municipalities; it was mainly masonry buildings that were affected. However, the observations clearly point out that the two types of structure suffered high damage (Figures 7 and 8).

The inappropriate reaction of the reinforced concrete structure is believed to be the cause, and can be explained by the failure during its implementation or in its structure. Note also that for the masonry structure the intensity of the earthquake is the first cause of degradation. This observation was also confirmed in 2003in the reports of the French Association of Earthquake Engineering (AFPS2003) and national earthquake engineering research center.

The second criteria, the age of the buildings, provides an answer concerning damage directly related to the materials used in the construction of these buildings. Until 1956, the buildings were constructed in masonry, later they were designed in reinforced concrete or in metallic structure. After the disasters of 1954 (Orléansville) and 1980 in Chlef, the codes of Earthquake-resistant building have been introduced to prevent and ensure the resistance of buildings to the event of an earthquake. The first code was decreed in 1956, and the last two are the Algerian Paraseismic Rules of 1988 (RPA 1988), and modified in 1999.

The analysis of data by building age group showed that buildings less than 20 years old suffered multiple damage; the same applies to buildings constructed between 1953 and the end of 2003. Low hazard resistance (Figure 9), despite the existence of the earthquake codes mentioned above. Therefore, the alternative explanation lies in the non-compliance with the earthquake rules and standards of 1956, 1988 and 1999. On the other hand, buildings constructed before 1952 have recorded little damage, this type of building was designed in masonry and there are still a few buildings of this type. Thus, most of the damage is due to poor maintenance and the higher magnitude of this earthquake.

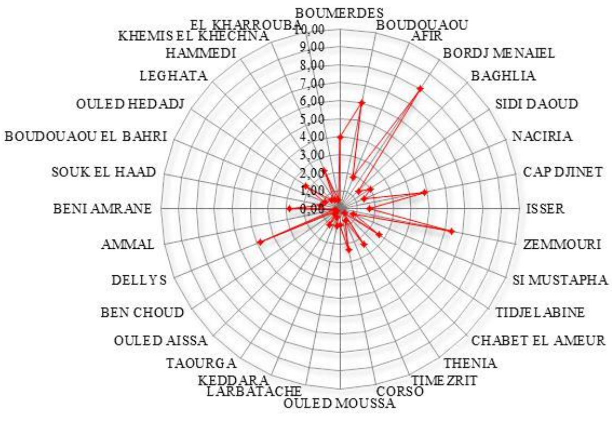

Figure 5: the degree of physical vulnerability of the municipalities of Boumerdes after the 2003 earthquake

(source: national earthquake engineering research center (CGS) data, and author processing)

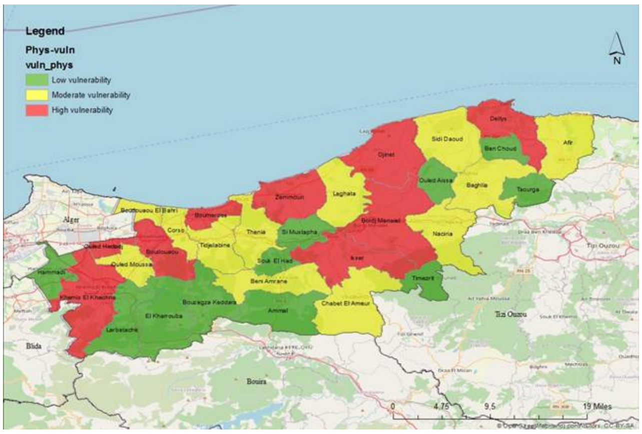

Figure 6: the specialisation of physical vulnerability of Boumerdes cities after the disaster 2003 (source: author)

Figure 7: Collapse by type of structure, on the left a masonry building and on the right a collective building with reinforced concrete at Dellys (source: Akreche design office, 2003)

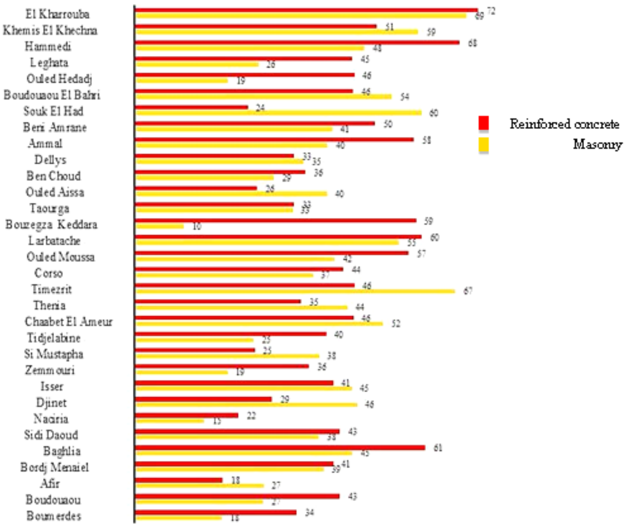

Figure 8: Damage rates by type of structure (masonry and reinforced concrete) compared to buildings damaged of the municipalities of Boumerdes on 21 May 2003 (source: national earthquake engineering research center (CGS) data and author treating, 2003).

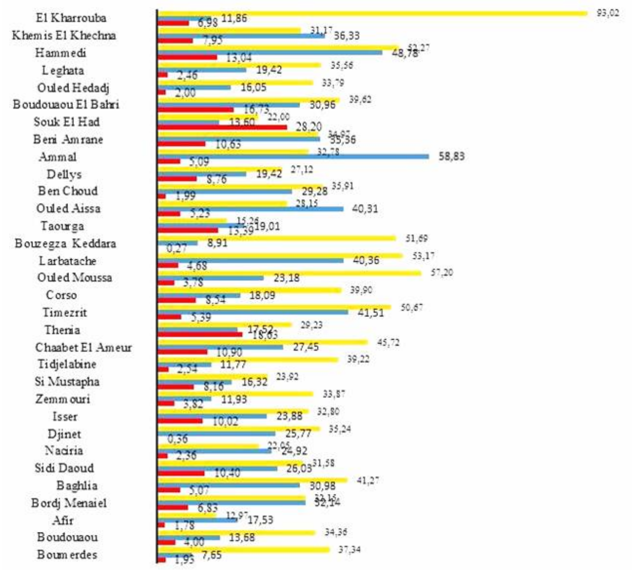

Figure 9: Degrees of damages by age and group of buildings in the Cities of Boumerdes in 2003 (source: 2003 data and author's treatment)

To check the non-compliance with earthquake regulations and the inappropriate use of reinforced concrete structures in damaged buildings, we examined the height of the buildings as a last criterion. At the end of 2002, there were two types of buildings throughout the territory of the province of Boumerdes, namely collective and individual buildings. Individual buildings are low, 1 to 2 floors, while collective buildings are three or more floors. We classified the damaged building data according to this categorization, and obtained the following results. The low-rise buildings suffered extensive damage and the rates were very high in most of the affected municipalities. However, collective buildings were little affected (Figures10 and 11). Low-rise buildings are self-constructed buildings. One explanation that we can raise is that until 2003, the building permit application did not require a civil engineering file, with the exception of public buildings. After the promulgation of the law n ° 04-05 of August 14, 2004 modifying and supplementing the law n ° 90-29 of December 1, 1990 relating to the development and town planning, the file of civil engineering became compulsory in the request of building permits. This explains the high damage rates in this type of building. For collective buildings, significant human losses were recorded as in Dellys and Boumerdes. In general these buildings are made by offices (OPGI and ex-EPLF) delegated by the Ministry of Housing and Town Planning. In carrying out the construction works of these type of buildings, it was therefore required to comply with earthquake-resistant standards. This is why we consider that the damage is due to the poor implementation of the structural system.

The damage to buildings caused by the earthquake of 21 May 2003 was considerable. The internal elements of the material challenges were very sensitive, they did not resist well to this natural phenomenon. Therefore, they were vulnerable before the earthquake, and this disaster revealed this hidden physical vulnerability in the most affected municipalities. Hence, the question we have to ask is: Why did the municipalities not suffer the same degree of damage? According toCutter (2012) “The causes of natural disasters are not only to be found in the physical process, but above all in the inability of local societies to cope with them”. It should be noted that the fact that the social aspect of vulnerability is now better known and this facilitates analysis in order to provide answers.

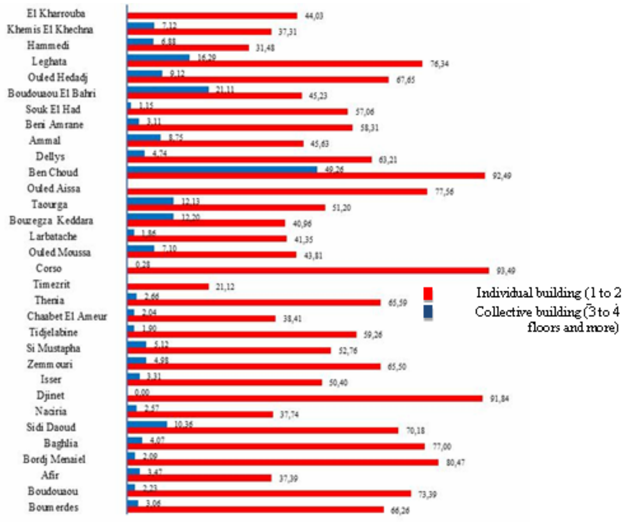

Figure 10: Degrees of damage by type of collective and individual building in Cities of Boumerdes in 2003 (source: CGS 2003 data and author's treatment)

Figure 11: We observe two cases, the total disappearance of the ground floor of a private residential building with1 to 2 floors, in the second case total disappearance of a collective building with 3 to 4 floors (Source:Japan Association of Earthquake Engineering (JAEE) et al., 2004).

Revealing the social and human vulnerability

In order to provide answers of disparities in the distribution of damage in different cities of Boumerdes Province, we analyse and assess the human and social vulnerability of this society. The choice of indicators specific to these vulnerabilities was inspired by previous research on this subject. These include work on the integration of the social vulnerability approach into analyses, following the example of the work of Cutter et al. (2000). Our objective is to propose an assessment of the situation of the populations in the municipalities before the seismic hazard of 2003, and how they participated in the fabric of the risk and the disaster of 2003.

The characteristics of the population and their residential environment had been examined, without going back to the origins of the underlying causes explaining this vulnerability. These variables provide an initial metric for modelling and estimating the social vulnerability of each municipality. Rather than using simple percentages, each social variable was standardized by first determining the ratio in each census of the municipality to the total number of that variable in the province. For example, to calculate the female gender vulnerability index, we compiled the number of women in each census municipality (column 2), as well as the total number of women in the province (column 3). The ratio of the number of women to the total number of women in the province was calculated (column 4), and this value (x) was divided by the maximum value (x) to create an index between 0 and 1.00.A Higher values indicate greater vulnerability (Table 2 and figure 12). All other human and social variables were standardized at the same way. Subsequently, the calculated index values were assigned to each municipality and the index values for each variable were summed to obtain a composite index score for each municipality (Figure 13). This value represents an overall measure of human and social vulnerability. In addition, these indices were also placed in quartiles and presented visually in four categories. Each indicator of social vulnerability can be examined independently and by municipality. However, this is a summary of all the measures that provide a broad overview of the spatial distribution of social and human vulnerability in the municipalities studied.

We estimated the scores for each municipality, i.e. those with a high score and put it in Arcmap application. The populations (figure 14) were indeed vulnerable before the seismic event of 2003. These are the municipalities of Brodj Menail, Boudouaou, Boumerdes, Naciria, Isser, Chabet El Ameur, Thenia, Dellys, Hammadi and Khemis El khachena.Before 2003, these municipalities were exposed to a probable natural event, so we consider that they were most sensitive to any type of natural hazard that could arise in the area. Hence we checked this sensitivity after the seismic disaster of 21 May 2003.

BOUMER DES	16617	203535	0,08	0,58
BOUDOU AOU	26662	203535	0,13	0,94
AFIR	6256	203535	0,03	0,22
BORDJ MENAIEL	26470	203535	0,13	0,93
BAGHLIA	7707	203535	0,04	0,27
SIDI DAOUD	7212	203535	0,04	0,25

NACIRIA	10759	203535	0,05	0,38
DJINET	9821	203535	0,05	0,34
ISSER	13792	203535	0,07	0,48
ZEMMOURI	10275	203535	0,05	0,36
SI MUSTAPHA	4387	203535	0,02	0,15
TIDJELABINE	6947	203535	0,03	0,24
CHABET EL AMEUR	15096	203535	0,07	0,53
THENIA	9475	203535	0,05	0,33
TIMEZRIT	5401	203535	0,03	0,19
CORSO	6347	203535	0,03	0,22
OULED MOUSSA	12669	203535	0,06	0,44
LARBATACHE	7640	203535	0,04	0,27
KEDDARA	4157	203535	0,02	0,15
TAOURGA	3626	203535	0,02	0,13
OULED AISSA	3385	203535	0,02	0,12
BEN CHOUD	4315	203535	0,02	0,15
DELLYS	13813	203535	0,07	0,48
AMMAL	4263	203535	0,02	0,15
BENI AMRANE	10511	203535	0,05	0,37
SOUK EL HAAD	2387	203535	0,01	0,08
BOUD. EL BAHRI	5061	203535	0,02	0,18
OULED HEDADJ	10887	203535	0,05	0,38
LEGHATA	5926	203535	0,03	0,21
HAMMEDI	13544	203535	0,07	0,48
KH. EL KHECHNA	28536	203535	0,14	1,00
EL KHARROUBA	4050	203535	0,02	0,14

Table 2: Index of women vulnerability by municipality in the province of Boumerdes, prior to 2003 (source: GCPH 1998 data and author's treatment)

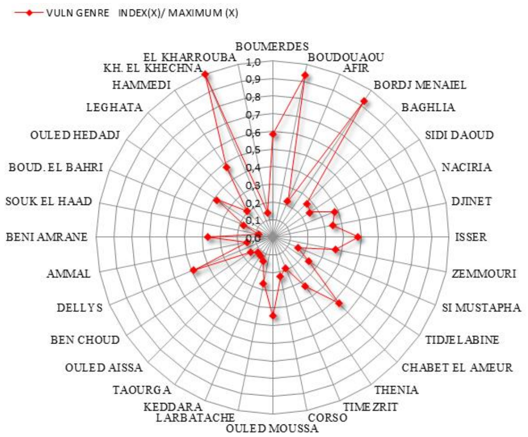

Figure 12: The vulnerability of Cities in theProvince of Boumerdes by gender (women) before the 2003 earthquake (source: GCPH 1998 data and author's graphic treatment)

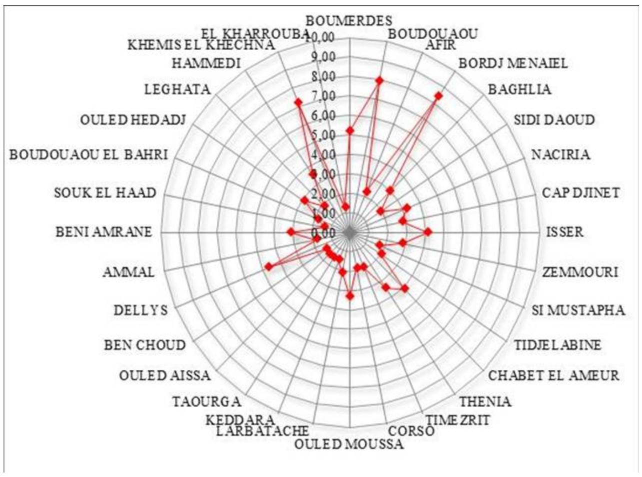

Figure 13: The social vulnerability index of populations in each Cities of the Province of Boumerdes before the 2003 earthquake (source: GCPH 1998 and author's treatment).

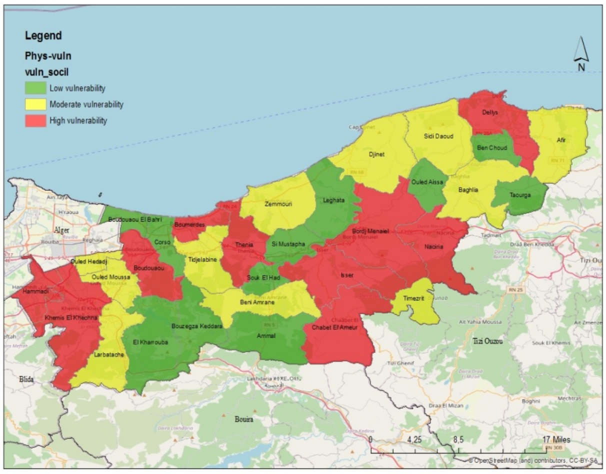

Figure 14: the specialisation of the social vulnerability of Boumerdes cities before the diasater of 2003 (Source: author)

Cities with high physical, social and human vulnerabilities

The Province of Boumerdes is exposed to natural hazards; the occurrence of the seismic hazard is all times evidenced. However, another component has played another crucial role in the disaster of 2003, the fragility of the constructions, since their poor resistance to natural hazards considerably increased their damage. The vulnerability of internal factors, concerning the elements at risk, has contributed to significant loss and damage in some municipalities as compared to others. The high degree of damage to the most physical objects was that of the towns of Boudouaou, Bordj Menail, Zemmouri, Cap Djinat, Dellys, Boumerdes, Beni Omrane and Tidjelabine, Ouled Hadadj, Khemis el Khachna and Isser.

By combining the physical vulnerability indices of the municipalities after the 2003 disaster with the social vulnerability indices of the populations before 2003, we obtain the most vulnerable, these are: Brodj Menail, Boudouaou, Boumerdes, Isser, Chabet El Ameur, Dellys, Khemis El khachena (figure 15).

Thus, we confirm that municipalities that had a high score in terms of social and human vulnerability before 2003 are also those that were severely affected after the earthquake disaster. Furthermore, the vulnerability of the physical factors of the elements at risk attests that the risk was present before the disaster, but only this vulnerability was hidden, and was revealed by the 2003 earthquake. Concerning the overall vulnerability of the Boumerdes province to natural hazards, it appears that the vulnerabilities have a spatial and temporal dynamic. Several physical, socio-economic and human factors have generated spatial variations in vulnerabilities in different municipalities, with different scales of damage and loss. This explains the intersection of physical vulnerability and social vulnerability (Figure 16) and how they shaped the 2003 disaster risk.

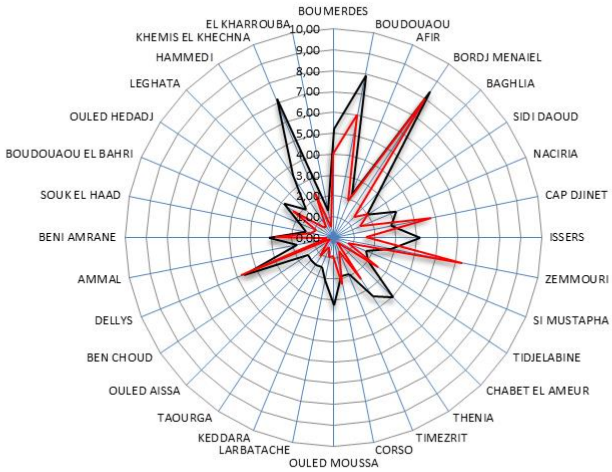

Figure 15: the overall vulnerability of municipalities in the province of Boumerdes before and after the 2003 earthquake, a high overall vulnerability (source: GCPH 1998, CGS 2003 and author).

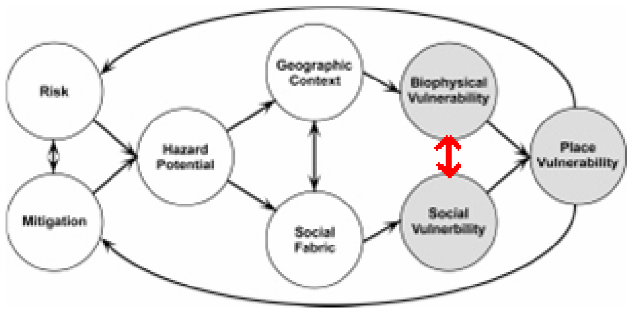

Figure 16: risk management model modified (source: Cutter and al. 2000 modified by author)

Conclusion

Tools to reduce risks and disasters in Boumerdes

Algerian municipalities are exposed to several natural events and the probability of dangerous events is high, the history of past events has left its mark on these territories. However, with each event, several material damages and human losses are recorded, despite the efforts made to reduce the damage. As a result, property damage and loss of life continue to increase in cities. Our discussions concern the need to review the methodology for assessing and preventing these natural risks.

Studying the social and human vulnerability of populations is very important in order to reduce the risk and implement a preventive policy in accordance with the human capacities of the populations and Algerian society.

This study has certainly highlighted how the social vulnerabilities of districts in the province of Boumerdes before the 2003 earthquake, contributed to the generation of the physical vulnerability factors of the objects of danger, and how these factors have reinforced over time the weakness and sensitivity of the physical materials.

In our case study we examine various vulnerable social and physical elements which, through their interaction and intersection, have contributed to the vulnerability of towns in the province of Boumerdes.

Indeed, the population of the Province of Boumerdes being without any means or capacity of defence, in addition to its limited socio-economic situation, the result of this unusual event is significant damage, first to buildings and then to the population itself, i.e. human losses. The implementation of a targeted risk management policy has become necessary. Therefore, all future economic and social investments should contribute to improving the quality of life of society, and necessarily integrate the vulnerability component in order to prepare it for any potential future event and risk of disaster.

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